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PLANT SCALE STUDIES OF THE MAGNESIUM CARBONATE WATER TREATMENT PROCESS

A. P. Black, et al

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The results indicate a number of significant advantages; primarily that the existing problem of sludge disposal in Melbourne's case is completely eliminated and at Montgomery is greatly reduced. All water is recycled within the process along with the three basic water treatment chemicals - lime, magnesium bicarbonate, and carbon dioxide. Other advantages found were increased floc settling rates, simplicity of operation and control, reduced costs when sludge treatment and disposal costs are considered, and more complete disinfection. In Melbourne's case, considerable energy would be conserved by on-site lime recovery.

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PLANT SCALE STUDIES OF THE MAGNESIUM CARBONATE WATER TREATMENT PROCESS

By

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ABSTRACT

The Magnesium Carbonate Process of water treatment has replaced alum in a portion of two (2) water plants in full scale studies conducted over the past two and one-half years. This new water treatment technology was compared to the presently used alum process in parallel treatment using identical units in Montgomery, Alabama and Melbourne, Florida.

The results of these studies indicate that this new process offers a number of significant advantages over the alum process. The primary advantage is that the existing problem of sludge disposal in Melbourne's case is completely eliminated and at Montgomery is greatly reduced. All water is recycled within the process along with the three (3) basic water treatment chemicals - lime, magnesium bicarbonate, and carbon dioxide. Other advantages found were increased floc settling rates, simplicity of operation and control, reduced costs when sludge treatment and disposal costs are considered, and more complete disinfection. In Melbourne's case, considerable energy would be conserved by on-site lime recovery.

In addition to the two full scale studies a number of special studies were conducted in Montgomery using a 50 gpm pilot plant. These studies showed almost complete removal of added cadmium by the highly adsorptive $Mg(OH)_2$ flocs and that it was not released during sludge carbonation and magnesium recycling.

This report was submitted in fulfillment of Project Number 12120 HMZ, by the Montgomery Water and Sanitary Sewer Board, under the partial sponsorship of the Environmental Protection Agency. Work was completed as of June 1973.

CONTENTS

SECTIONS		Page
I	Conclusions	1
II	Recommendations	3
III	Introduction	7
IV	Description of Project Phases	17
V	Results and Discussions	33
VI	References	93
VII	Appendices	95

FIGURES

No.		Page
1.	Magnesium Recycle Magnesium Process Flow Diagram	10
2.	Lime Recovery Magnesium Process Flow Diagram	12
3.	Lime and Magnesium Recovery Magnesium Process Flow Diagram	14
4.	Magnesium Demonstration Pilot Plant Layout	18
5.	Details of Rapid Mix Units and Chemical Additions - Montgomery, Alabama	22
6.	Flocculation pH Control System - Montgomery	23
7.	Montgomery WTP Solids Handling Facilities	25
8.	Solubility of Magnesium as a Function of CO_2 Partial Pressure	26
9.	Sludge Carbonation pH Control System - Montgomery	28
10.	Layout of Melbourne Water Plant Converted to Include the Magnesium Process	30
11.	Comparison of Theoretical Solubility of $Mg(OH)_2$ with Observed Jar Test and Pilot Plant Values	35
12.	Effect of pH on Coliform Survival - Laboratory Studies	40
13.	Thickening Characteristics of Alum and Magnesium Studies	42
14.	% Sludge Solids Versus Vacuum Filter Rate - Montgomery	47
15.	Fruendlich Isotherm for Carbon Adsorption of Organic Color with Activated Carbon	46

No.		Page
16.	Process Control Points and Sampling Locations - Montgomery	53
17.	Relationship Between Raw and Settled Turbidity as a Function of Time and Magnesium Dosage - Montgomery	56
18.	Montgomery Stabilized Water - Total and Magnesium Hardness	57
19.	Make-up Magnesium Cost as a Function of Coagulation pH - Montgomery	59
20.	Lime and CO_2 as a Function of Coagulation pH - Montgomery	60
21.	Lime, CO_2, and Magnesium Total Cost as a Function of Coagulation pH - Montgomery	61
22.	Lime and Magnesium Costs as a Function of Coagulation pH - Montgomery	63
23.	Corrosion Rates for Alum and Magnesium Treated Water - Montgomery	68
24.	Raw Water Color and Treated Water Color as a Function of Time and Magnesium Dosage	74
25.	Magnesium Sinks and Sources as a Function of Time - Melbourne	76
26.	Color/Magnesium Ratio as a Function of Time - Melbourne	78

TABLES

No.		Page
1.	Cities Treating Soft Surface Waters	11
2.	Cities Treating Moderately Hard, Turbid Surface Waters	13
3.	Cities Treating Hard Turbid Surface Water	15
4.	Typical Range in Raw Water Characteristics Tallapoosa River, Montgomery, Alabama	20
5.	Typical Range in Raw Water Characteristics Lake Washington, Melbourne, Florida	29
6.	Typical Pilot Plant Results	36
7.	Pilot Plant Results During Rapid Water Quality Deterioration	37
8.	Summary of Coliform Survival Laboratory Studies	39
9.	Carbon Adsorption of Released Organic Carbon	45
10.	Carbon Adsorption of Released Organic Color	45
11.	Use of Chlorine to Reduce Organic Color	47
12.	Effectiveness of Alum in Removing Cadmium	47
13.	Effectiveness of Lime in Removing Cadmium from Water in Jar Tests	48
14.	Effectiveness of Magnesium Hydroxide in Removing Cadmium from Water in Jar Tests	48
15.	Pilot Plant Results - Cadmium Study	50
16.	Control Systems and Sampling Location	55
17.	Raw Water Analyses and Alum Dosages, Montgomery, Alabama	63
18.	Vacuum Filter Data, Montgomery, Alabama	66

No.		Page
19.	Comparison of the Magnesium and Alum Treatment Processes at Montgomery	69
20.	Estimation of Capital Cost for Montgomery's Plant Conversion	72
21.	Chlorine Demand Test	79
22.	Leaf Filter Test Results - Melbourne	80
23.	Full Scale Vacuum Filter Results - Melbourne	80
24.	Melbourne Sludge Thickening Study	81
25.	Design Table Summary	86

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SECTION I
CONCLUSIONS

1. The use of magnesium carbonate as a recycled coagulant has been found to equal or exceed the results obtained by the use of alum in every aspect of water treatment including: water quality produced, operational characteristics, economy, and adaptability over a wide range of raw water qualities.
2. The Montgomery raw water is too soft to consider lime recovery; however, in Melbourne's case, where lime recovery is economically attractive, no solid or liquid discharge will result. The coagulated color will be converted to carbon dioxide on calcination and the three primary water treatment chemicals (magnesium, carbon dioxide and lime) recycled within the process.
3. In Montgomery, the easily dewatered filter cake will be available for use as a soil pH stabilizer. Considerable quantities of limestone are presently purchased in Alabama for this purpose each year.
4. The increased floc density produced by the magnesium process will allow higher clarifier loading rates. In Melbourne the present loading rates were doubled without a deterioration in the quality of the clarifier effluent.
5. Reduced treatment costs were found when sludge dewatering and ultimate disposal costs were considered. In Melbourne this cost savings would be in excess of $100,000 per year for a water production of 10 MGD. In evaluating the results of these studies, it should be kept in mind that from the standpoint of treatment costs, they represent the most unfavorable conditions

for this process. The greatest benefits from the new technology will be obtained by major cities treating hard waters containing sufficient lime to recalcine.

6. The chemical quality of the treated water was improved in both the Melbourne and Montgomery studies. In Montgomery the increase in finished water alkalinity using the Magnesium Process reduced the corrosion rate to one-half the value found for the extremely soft alum treated water. In Melbourne a considerably softer water would be produced during the winter months.

7. Plant personnel demonstrated their proficiency in the operation of the process under difficult conditions. The nature of the process is such that pH control at three (3) critical points is the primary method of insuring adequate treatment, producing excellent quality over a wide range of influent quality. The process was found to be easily automated and controlled.

8. The full scale use of this new process is compatible with most existing water treatment plants requiring a minimum of land area and capital cost. The conversion of most existing alum treatment plants to this new technology involves few internal process changes and only minor piping changes to add the necessary recovery and recycling units.

SECTION II
RECOMMENDATIONS

E.P.A. Project 12120 HMZ recently completed in Montgomery and Melbourne has shown that this process is practical for soft, turbid waters and moderately hard waters high in organic color. Magnesium recovery and recycle has been shown to be practical and economically feasible. This project has provided design criteria which are applicable to many water plants utilizing the types of raw water investigated in this project. The need for extensive pilot studies by each of these type plants is eliminated.

Hard turbid water presents the most serious problems in sludge disposal due primarily to the large quantity of sludge to be treated. While these sludges generally dewater more readily than soft water sludges, high disposal costs can result due to the quantity to be hauled to a suitable landfill. Lime recovery from the precipitated calcium carbonate has been to date considered unfeasible due to the high silt content; however, the use of flotation separation of the calcium carbonate now makes lime recovery possible. All of the unit processes have been demonstrated in the laboratory; however, pilot or full scale studies have been conducted in only limited areas. In the application of new technology, considerable caution must be exercised. In the case of this process the use of pilot and/or demonstration plants are required before considering such a drastic process change to a full scale plant operation.

Work completed at Dayton, Ohio is directly applicable to only a very few cities treating clear ground water. The magnesium carbonate production studies carried out to date have been conducted on a batch basis with little attention given to obtaining design information. The influence of raw

water impurities on the magnesium compounds has not been evaluated nor the various means of removing these impurities prior to magnesium carbonate precipitation.

At the present time, there have been three E.P.A. funded projects related to the overall magnesium process. The first project was a laboratory study conducted at Gainesville, Florida, Project 11060 ESW, and concluded in May of 1971. The second was the Demonstration Project 12120 HMZ reported on here. The initial objectives of this project were concerned with the treatment of a very soft, low magnesium water at Montgomery, Alabama with no consideration given for magnesium production. The extension of this project in Melbourne, Florida, studied the application of the process for treatment of a much harder, highly colored, low turbidity water. The third project, in Gainesville, Florida, 12130 HRA, was for the treatment of municipal and industrial wastes. This latter project has been completed, and a final report submitted.

A comprehensive research project, 802800, has also been initiated to study the application of the lime and magnesium recovery aspects of this process on a hard, high magnesium, turbid surface water at Johnson County, Kansas. The specific objectives of the proposed research are:

1. Determine the technical feasibility of separating calcium carbonate from the clay turbidity by froth flotation. This must be accomplished during wide variations in raw water quality. The seasonal effects on both the sludge character and the flotation process should be evaluated.
2. A study of the production of magnesium compounds from a relatively poor quality raw water in continuous flow, pilot scale studies.
3. Development of design information for all required unit operations where recovery is found to be technically feasible.
4. Conduction of a economic analysis for full scale application of lime and magnesium recovery. A

projection as to the cost effectiveness of these recovery processes as a function of plant size and raw water quality will be made.

The studies in Melbourne have shown the process to be applicable to color removal at moderately high levels. A sample of the total effluent from an unbleached southern kraft pulp mill was collected for laboratory jar testing. This effluent had received only settling as treatment and had the following characteristics:

pH	8.3
Total Alkalinity (as $CaCO_3$)	328 mg/l
Color (Pt.-Co. Units)	530 mg/l

A number of jar tests were run using different dosages of magnesium carbonate, coagulating at a constant pH of 11.3. A summary of these tests is as follows:

Chemical Dosages

Magnesium Dosage* (mg/l as $CaCO_3$)	350
Lime Dosage mg/l as $Ca(OH)_2$	430

Treated Stabilized Waste Characteristics

pH	8.5
Alkalinity as $CaCO_3$	213
Color (Pt.-Co. Units)	53
% Color Removal	90

For comparative purposes a brief study was made of the use of alum for the coagulation of the color present. Three hundred (300) mg/l of alum produced a treated effluent with a COD of 205 mg/l and a color of 93 mg/l. This indicates a COD removal of 64% and a color removal of 83%. At an alum cost of 2.1¢ per pound a chemical cost of greater than $52 per million gallons could be expected. Based on these limited

*Magnesium dosages are expressed in terms of calcium carbonate equivalents for simplicity. The actual magnesium form used may be magnesium sulfate, magnesium carbonate, magnesium bicarbonate, etc.

studies, the chemical cost for the magnesium process would be approximately $20.00 per million gallons.

Presently, lime treatment of these wastes is considered most often when color removal is required in conjunction with conventional treatment. The use of the magnesium process would appear to offer the following advantages over the Massive or Stoichiometric Lime Processes:

1. The sludge produced should be considerably easier to dewater due to the higher calcium carbonate content.
2. Due to magnesium recycle, a lower coagulation pH is possible generally in the range of 11.2 to 11.4.
3. Chemical costs should be considerably less due to the lower coagulation pH and subsequent reduced lime requirements.
4. Using magnesium hydroxide as a coagulant, a much higher degree of color removal and total organic carbon should be achieved. This is based on a very preliminary study with the data presented earlier.

The discussion concerning the potential for the magnesium process for the treatment of a kraft unbleached pulp mill waste illustrates one possible application for industrial waste treatment which should be studied in detail. Similar discussions could be included for many other colored wastes such as dispersed textile dye wastes, treatment of fluoride wastes, removal of many heavy metal constituents of industrial wastes; and silica removal to meet industrial water treatment requirements. It is important that this new technology be evaluated over a wide range of applications, first in the laboratory and later in pilot or demonstration scale projects if initial results are encouraging.

SECTION III
INTRODUCTION

In November, 1972, the City of Montgomery, Alabama, began drinking water produced using a totally new concept in water treatment. This new process utilizes chemical recycle and recovery to eliminate waste discharges and reduce the cost of water treatment. The project at Montgomery was sponsored by the Environmental Protection Agency, the American Water Works Association Research Foundation and the Montgomery Water and Sanitary Sewer Board. The study began in pilot scale and culminated in a successful plant scale application producing five million gallons of water per day.

The development work for this system of water treatment began in the 1950's in Dayton, Ohio. Dr. A. P. Black, working with the City of Dayton to reduce the waste sludge from the water treatment plant, developed a technique for the separation of magnesium hydroxide from the calcium carbonate component of the sludge.[1] Dayton's water supply is obtained from clear well water very high in calcium and magnesium hardness. The softening sludge produced is very high in magnesium hydroxide which had to be separated prior to lime recalcination. Carbon dioxide produced in lime recalcination is used to selectively dissolve the magnesium hydroxide as the soluble bicarbonate. The clear magnesium bicarbonate solution is separated by thickening and discharged to a nearby water course.

Lime recalcination with sludge carbonation, begun in 1957, has been operating very successfully resulting in the elimination of waste sludge discharge and at the same time greatly reducing the chemical cost of water treatment.[2] However, Dayton has been advised by the State of Ohio that this clear magnesium bicarbonate discharge represents a pollution problem, due to the high dissolved solids, that should be eliminated. Dr. Black found after extensive laboratory and pilot scale work that extremely pure magnesium carbonate could

be easily and inexpensively precipitated from the magnesium bicarbonate liquor.[3].

During this same time period, Dr. Black discovered that froth flotation provided a highly selective method of separating relatively pure calcium carbonate from clay, silt, or other common raw water contaminants. He found this to be true only if the coagulant used has been removed prior to the flotation process.

Another discovery was that the magnesium carbonate produced from the Dayton plant was an excellent coagulant for water and waste water and that it could be recovered and recycled. Drs. A. P. Black and C. G. Thompson expanded the development of this technology in laboratory studies sponsored by E.P.A. Project 11060 ESW at the University of Florida. It was found that this coagulant compared favorably with alum treatment for a large number of natural waters studied in the laboratory.[4,5,6]

These four basic discoveries -- separation of magnesium hydroxide from calcium carbonate; flotation of calcium carbonate from raw water impurities; the use of magnesium as a recycled coagulant; and the production of magnesium carbonate from the sludges of waters high in magnesium concentration -- meshed together to produce an entirely new system of water treatment. This coagulation system is a unique combination of water softening and conventional coagulation. Sufficient lime slurry is added to a water containing magnesium carbonate or to which magnesium carbonate has been added, precipitating both magnesium hydroxide, which has properties similar to aluminum hydroxide, and calcium carbonate. Carbonation of the sludge selectively dissolves the magnesium hydroxide as magnesium bicarbonate which can be recovered by thickening and vacuum filtration for recycle and reuse. The filter cake, composed of calcium carbonate and clay, is reslurried and the calcium carbonate floated off for recalcination. The carbon dioxide produced in the recalcination is used both for sludge

carbonation and finished water stabilization. The flotation underflow, clay, is dewatered and disposed of as landfill.

There are three general applications of the processes involved:

1) The use of magnesium as a coagulant with the recycle of magnesium bicarbonate and sludge dewatering as an integral part of the process. This would be applicable to those waters relatively low in magnesium content with insufficient lime usage to consider lime recovery. The flow diagram is illustrated in Figure 1. Table 1 illustrates a number of cities whose raw water characteristics fall into this category.

2) Magnesium recycle using flotation for calcium carbonate beneficiation prior to lime recovery. The carbon dioxide produced in lime recovery is used for sludge carbonation and finished water stabilization. The impurities separated by flotation would be dewatered and disposed of as landfill. This would be applicable for waters moderately high in hardness with sufficient lime usage to make recalcination economically feasible. This process is illustrated in Figure 2 while Table 2 lists representative cities for this category along with their raw water characteristics.

3) Precipitation of the magnesium present in the hard raw water, use of lime recovery with flotation beneficiation, and magnesium carbonate production. This, of course, would be applicable to waters high in magnesium content with sufficient lime usage to consider lime recovery. The units required are shown in Figure 3. Table 3 illustrates typical cities in this category.

The primary emphasis of this new water treatment process is the elimination of sludge disposal problems by the recovery and reuse of the three (3) water treatment chemicals used - lime, carbon dioxide, and magnesium.

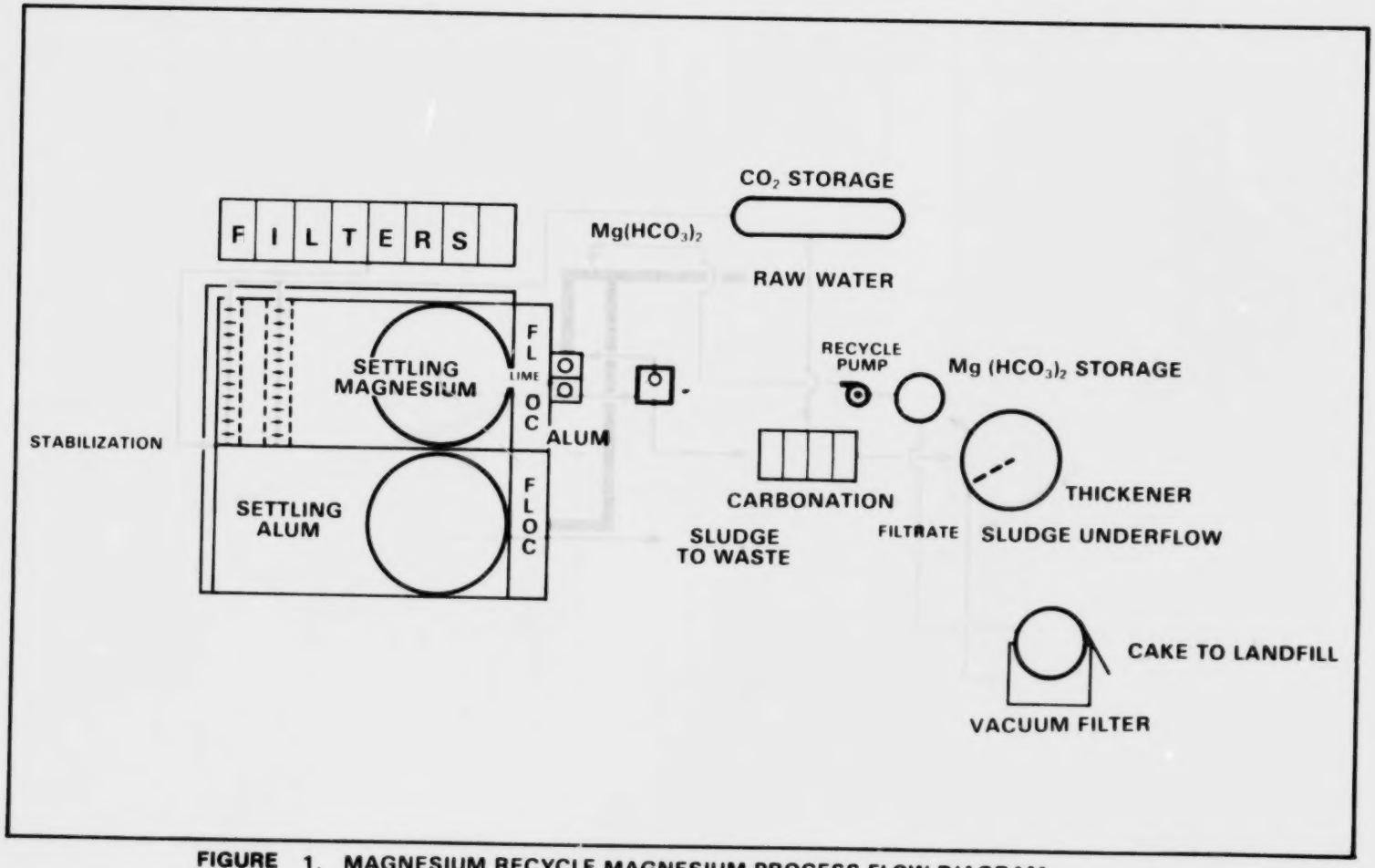


FIGURE 1. MAGNESIUM RECYCLE MAGNESIUM PROCESS FLOW DIAGRAM

TABLE 1. CITIES TREATING SOFT SURFACE WATERS(a)

CATEGORY 1

City	Source of Supply	Chemical Characteristics			Turbidity		
		Mg++ (b)	CH (c)	TH (d)	Avg.	Max.	Min.
Baltimore	Three Rivers (Imp.)	2-3	35	43	<1	3	0.1
Albany	Imp. Supplies	3	23	43	5	15	0
Bridgeport	Imp. Supplies	1	9	25	-	-	-
Tulsa	Imp. Supplies	2	86	86	7	13	4
Providence	Pawtuxet River	<1	5	10	<1	<1	<1
Newark	Imp. Rivers	3	17	19	-	-	-
Lynn, Mass.							
Richmond	James River	2	34	40	44	274	10
Norfolk	Two Impoundments	5	28	52	8	19	3
Atlanta	Chattahoochee River	1	14	14	27	200	5
Birmingham	Lake Purdy Imp.	<1	7	7	-	-	-
Mobile	Big Creek Imp.	<1	3	6	50	111	32
Montgomery	Tallapoosa River						
Savannah	Abercorn Creek	4	17	18	30	43	21
Shreveport	Cross Lake	4	25	42	17	27	8
Jackson	Pearl River	1	16	35	60	1000	8
Charlotte	Catawba River	1	16	13	25	142	5
Greensboro	Imp. Creeks	2	26	30	54	340	3

(a)All data compiled from annual reports and/or U.S.G.S. Water Supply Paper 1812

(b)Magnesium as Magnesium

(c)Calcium Hardness

(d)Total Hardness

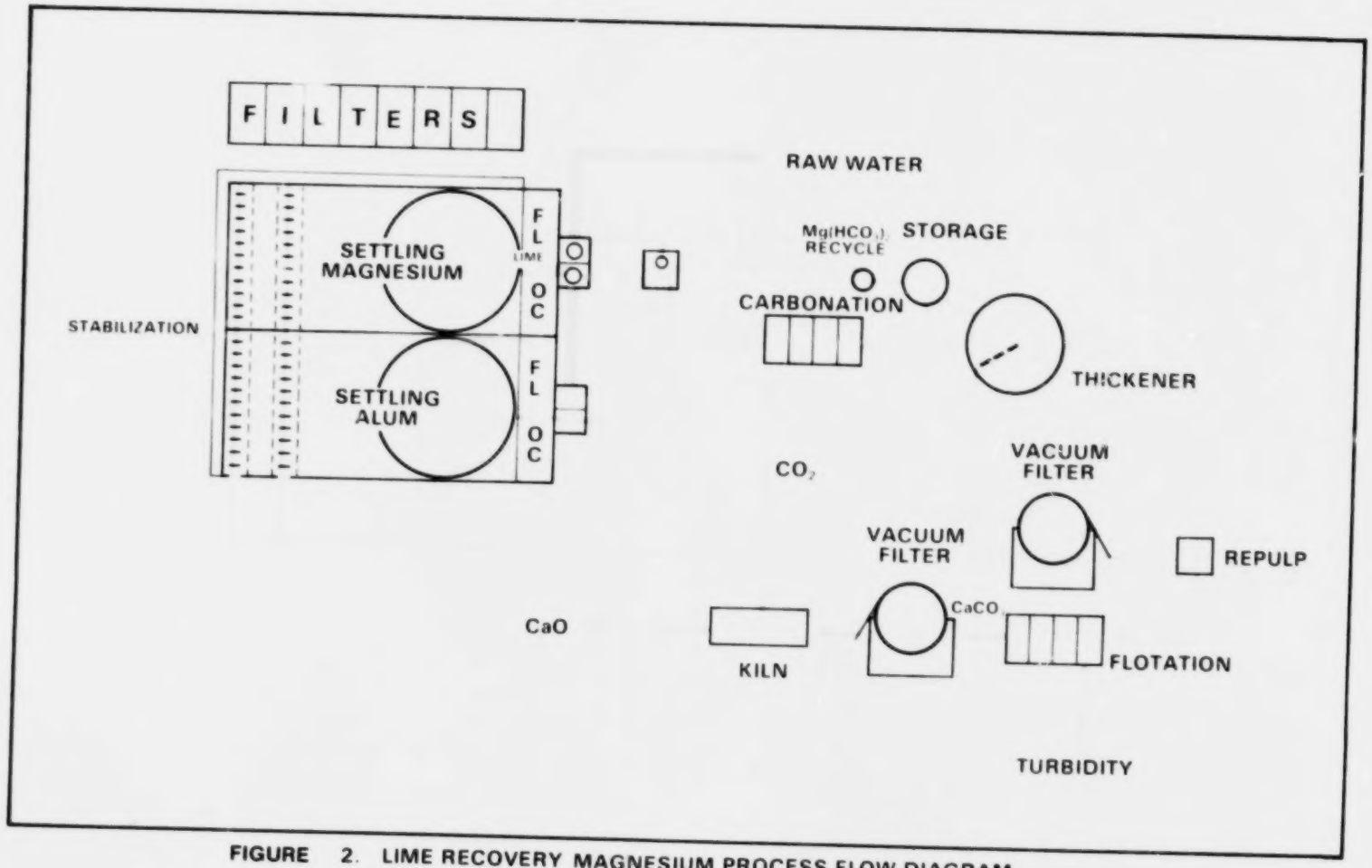


FIGURE 2. LIME RECOVERY MAGNESIUM PROCESS FLOW DIAGRAM

TABLE 2. CITIES TREATING MODERATELY HARD, TURBID SURFACE WATERS[a]

CATEGORY 2

City	Source of Supply	Chemical Characteristics			Turbidity		
		Mg++ (b)	CH (c)	TH (d)	Avg.	Max.	Min.
Chicago	Lake Michigan	11	108	128	15	160	1
Cleveland	Lake Erie	7	94	127	9	140	1
Detroit	Detroit River	7	80	100	11	20	2
Milwaukee	Lake Michigan	10	108	131	4	38	1
Toledo	Lake Erie	8	89	186			
Erie, Pa.	Lake Erie	10	92	121	9	40	1
Buffalo	Lake Erie	9	95	131	12	200	1
Philadelphia	Delaware River	6	34	67	22	36	13
Philadelphia	Schuylkill River	15	65	153	27	85	9
Washington, D.C.	Potomac River	8	70	101	49	600	6
Pittsburg, Pa.	Allegheny River	10	6	120	139	25	-
Pittsburg, Pa.	Monongehela River	5	4	112	-	-	-
Louisville, Ky.	Ohio River	10	74	131	101	800	4
Paterson, N.J.	Several Streams	6	51	69	10	13	7
Grand Rapids	Lake Michigan	11	109	130	6	20	1
Rochester, N.Y.	Lake Ontario	10	92	127	6	40	1
Evansville, Ind.	Ohio River	10	70	136	102	620	6
Akron, Ohio	Cuyahoga River	7	74	107	5	36	1
Chattanooga	Tennessee River	5	52	73	25	340	15
Nashville	Cumberland River	8	65	81	29	60	13
Youngstown	Meander Creek (Imp.)	6	36	86	-	-	-
Dallas, Texas	Impounded	6	119	164	62	732	15
Dallas, Texas	Lakes	7	110	152	49	1120	13
Ft. Worth	Imp. Lakes	8	128	139	22	40	5
Cincinnati	Ohio River	9	40	137	70	1100	1
Corpus Christi	Nueces River	6	119	164	62	732	15
Tampa	Hillsboro River	6	106	125	Seasonal organic color		
Gary	Lake Michigan	11	108	128	5	160	1

(a)All data compiled from annual reports and/or U.S.G.S. Water Supply Paper 1812

(b)Magnesium as Magnesium

(c)Calcium Hardness

(d)Total Hardness

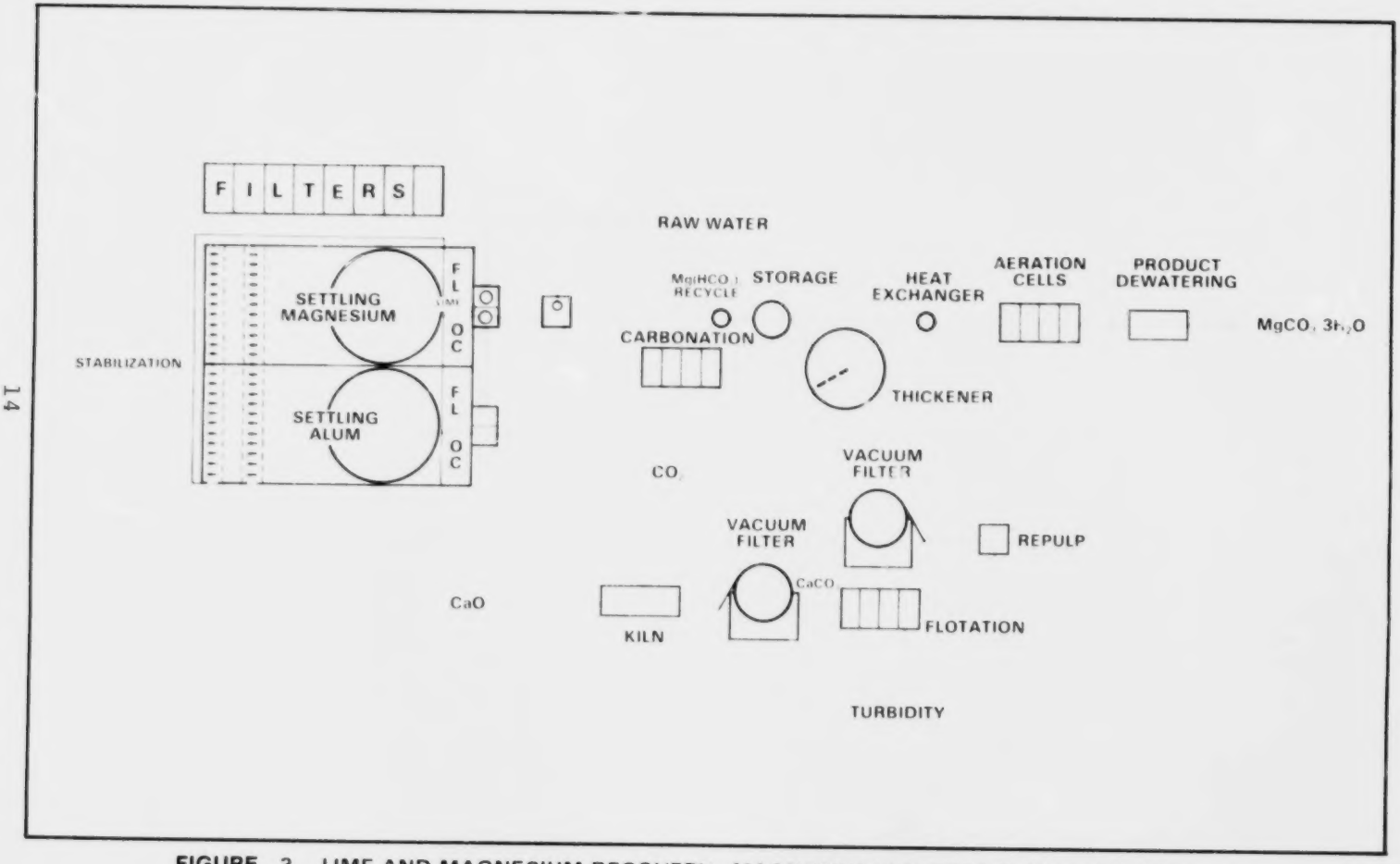


FIGURE 3. LIME AND MAGNESIUM RECOVERY MAGNESIUM PROCESS FLOW DIAGRAM

TABLE 3. CITIES TREATING HARD TURBID SURFACE WATER[a]

CATEGORY 3

City	Source of Supply	Chemical Characteristics			Turbidity		
		Mg++ (b)	CH (c)	TH (d)	Avg.	Max.	Min.
Des Moines	Racoon River	33	244	331	50	1330	1
Kansas City, Mo.	Missouri River	16	163	218	800	1800	70
Kansas City, Ka.	Missouri River	13	172	231	810	4800	10
Flint, Mich.	Flint River	24	208	276	15	23	4
Minneapolis	Mississippi River	16	158	185	7	60	1
St. Paul	Mississippi River	10	164	178	1	2	0
Omaha	Missouri River	23	172	245	280	780	15
Columbus	Scioto River	26	159	272	40	110	15
Columbus	Big Walnut Creek	15	92	152	13	28	3
St. Louis	Missouri River	17	153	208	350	1750	20
St. Louis	Missouri River	17	154	206	383	2500	20
Oklahoma City	Lake Hefner	26	143	246	6	6	6
Fort Wayne, Ind.	St. Joseph River	20	225	279	75	735	30
Austin, Texas	Colorado River	19	155	187	10	91	6
Phoenix, Ariz.	Salt River	15	122	205	-	-	-
Lima, Ohio	Upland Res.	23	136	252	-	-	-
Phoenix, Ariz.	Verde River	14	144	184	-	-	-
Topeka, Ka.	Kansas River	23	203	292	912	1120	375
New Orleans	Mississippi River	11	108	128	5	160	1
St. Louis County	Missouri River	17	145	208	322	2195	0

(a)All data compiled from annual reports and/or U.S.G.S. Water Supply Paper 1812

(b)Magnesium as Magnesium

(c)Calcium Hardness

(d)Total Hardness

PROJECT ORGANIZATION

The E.P.A. Demonstration Project 12120 HMZ was a natural outgrowth of the laboratory research reported previously, Project 17060 ESW. The Montgomery Water and Sanitary Sewer Board sponsored the project, however, financial support was also obtained from the American Water Works Association Research Foundation. An additional E.P.A. Research Grant award was made to the Montgomery Water and Sanitary Sewer Board to extend the application of this project to Melbourne, Florida. In addition, the City of Melbourne, Florida utilized a considerable portion of the Montgomery equipment which resulted in both an expedited project start-up date as well as financial savings. Smith & Gillespie Consulting Engineers, Inc., Jacksonville, Florida, Melbourne's consultants, were directly involved in planning and carrying out the Melbourne portion of the study and are now in the process of designing a full scale installation for Melbourne.

PROJECT OBJECTIVES

The objectives were:

1. To evaluate the process in full scale operation as to the technical and operational characteristics in the treatment of both a highly colored, and a soft, highly turbid surface water.
2. To determine if color or other raw water contaminants release on magnesium recovery would prove to be a problem.
3. To develop design information for all unit operations involved.
4. To develop economic information concerning all aspects of the process.
5. To perform selected studies in the areas of taste and odor, heavy metals, dissolved organics and new sources of make-up magnesium.

SECTION IV
DESCRIPTION OF PROJECT PHASES

The project was divided into three distinct phases; a 50 gpm pilot operation in Montgomery, a 5 MGD full scale study in Montgomery, and a 2 MGD full scale study in Melbourne. The Montgomery pilot studies were conducted for the purpose of:

1) Providing design information for subsequent full scale studies.
2) Training plant operators.
3) Evaluating potential process control problems.
4) Performing special studies.

In both the Montgomery and Melbourne full scale studies, parallel treatment with the alum process using essentially identical units was also accomplished. In a practical sense, in each location these studies resulted in the simultaneous operation of two water treatment plants using dramatically different processes. This was accomplished with existing personnel in both applications.

PILOT PLANT DESCRIPTION
MONTGOMERY, ALABAMA

The pilot plant operation began in November, 1971 and the studies were concluded in September of 1972. A photograph of the pilot facilities is shown in the Appendix.

The flow sheet for the pilot plant is shown in Figure 4. The major equipment utilized consisted of the following:

- 10 ft. diameter reactor-clarifier
- 5 ft. diameter thickener
- dual cell 15" X 15" carbonator (Galigher #15 flotation cells)

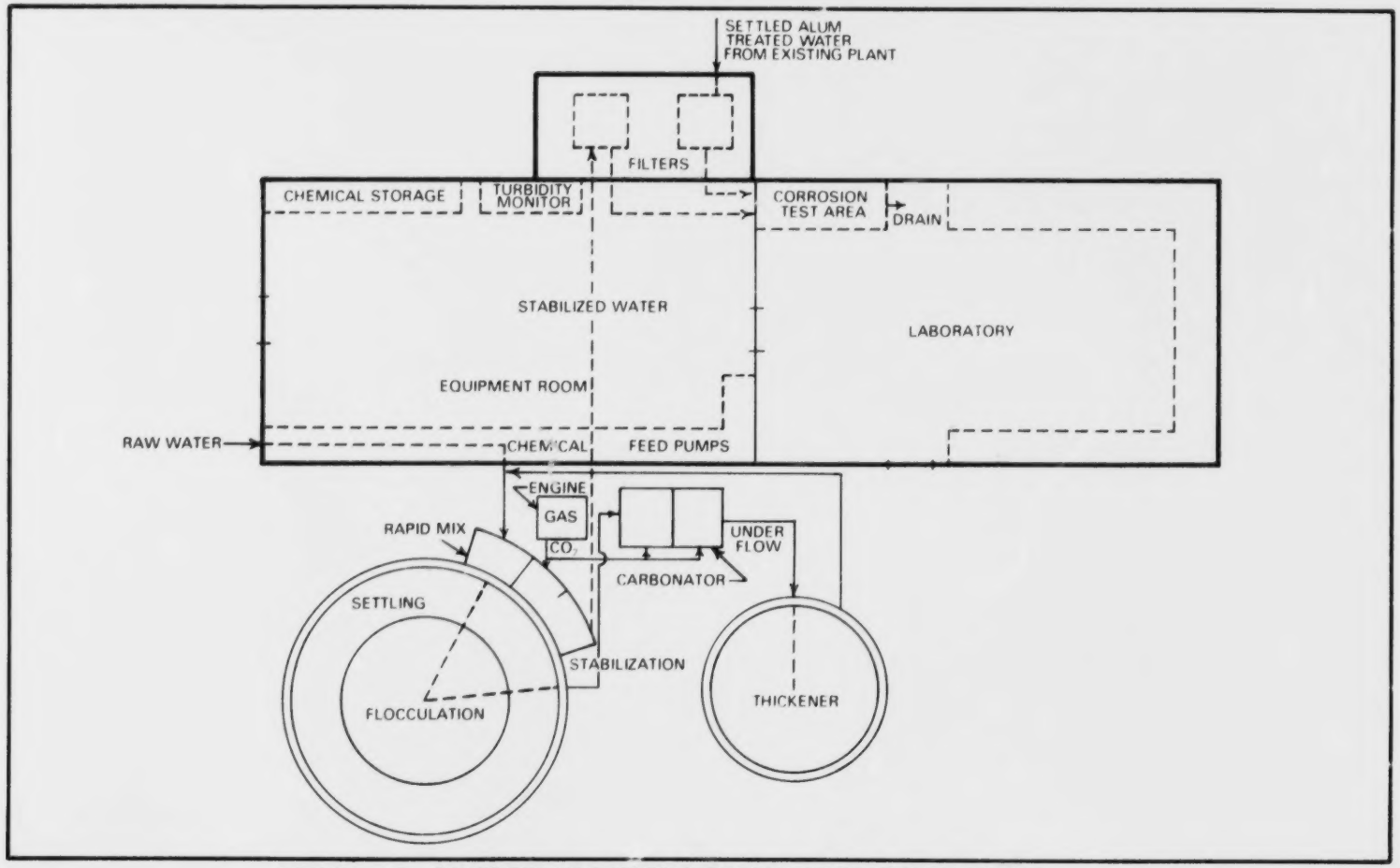


FIGURE 4. MAGNESIUM DEMONSTRATION PILOT PLANT LAYOUT

- Wallace and Tiernan A747 diaphragm solution pumps
- (2) 1-1/2' X 1-1/2' pilot filters using sand and anthracite media
- Continuously recording turbidmeter
- 7.5 horsepower natural gas engine

Raw water was obtained prior to pre-chlorination and regulated by a control valve to maintain the desired flow rate. Recycled magnesium bicarbonate, make-up magnesium sulfate, and lime were added to the raw water in successive order. Recycled sludge from the clarifier underflow was added to the rapid mix. The settled water was stabilized using the exhaust from the natural gas engine. Two stage settled water stabilization was used during a portion of the study by introducing carbon dioxide into the transfer line between the clarifier and filter.

The clarifier underflow was carbonated using pure carbon dioxide, in a Galigher #15 dual cell flotation machine. During periods of the study, exhaust gas was also used for sludge carbonation. The 5 ft. diameter thickener was used for solids-liquid separation, the overflow magnesium bicarbonate recycled to the raw water and the underflow to disposal or special studies.

Recycled sludge was provided for the following purposes:

1) Recycled calcium carbonate increases magnesium precipitation kinetically as well as quantitatively as reported by several early investigators.[7,8,9,10]

2) A portion of the magnesium hydroxide fraction of the sludge reacts with the recycled magnesium bicarbonate as well as the natural bicarbonate alkalinity and carbon dioxide in the raw water. This solubilized magnesium carbonate is effective for coagulation when reprecipitated; however,

some coagulated turbidity is also released. The overall effect is difficult to evaluate but is generally considered to be of some value.

3) The preformed calcium carbonate recycled acts as a seed or nucleus for precipitation preventing a build-up on mechanical equipment.

4) The excess causticity in the sludge water, pH 11.40, reduces the lime requirements slightly. The precipitation reactions occur rapidly and produce small dense flocculent particles. Even at maximum flocculation speeds the floc tends to settle from suspension.

MONTGOMERY FULL SCALE STUDIES

Figure 1 is the flow diagram of the Montgomery plant as converted for the study. This plant was an excellent facility for this project as only minor alterations were required to produce parallel plants with almost identical treatment units. Rapid mixing could not be provided for the alum process, but jar tests indicated that with the ample time provided in the flocculator, floc formation was not affected. A partial analysis of Montgomery's raw water is shown in Table 4.

TABLE 4. TYPICAL RANGE IN RAW WATER CHARACTERICS
TALLAPOOSA RIVER, MONTGOMERY, ALABAMA

pH	Alkalinity (mg/l)	Hardness (mg/l) (As $CaCO_3$)	Magnesium (mg/l)	Color (mg/l) (Pt-Co)	Turbidity (mg/l) (JTU)
6.6-7.0	10/22	10-22	0-5	5-60	2-300

The description of the plant facilities is in the order of occurrence.

RAPID MIX AND FLOCCULATOR

Figure 5 illustrates the recycle and chemical feed points using the two rapid mixers in series which provides a total detention time of four minutes at a rate of 5 MGD. Recycled magnesium bicarbonate was added to the raw water immediately prior to rapid mixing while uncarbonated recycled sludge and magnesium sulfate* were added in rapid mixer #1. Lime was added between rapid mixers #1 and #2 adjusting the pH to the desired value.

Lime feed was controlled automatically using a pH probe in rapid mixer #2, coupled to a pH controller and S.C.R. controlled pump as shown in Figure 6. Flocculation was carried out using conventional reel type variable speed flocculators normally operated at the maximum speed.

SETTLING-CARBONATION

The Montgomery plant utilizes conventional horizontal settling basins with mechanical sludge removal in the first half. Approximately two-thirds of the basin was used for settling with the remaining third used for two stage stabilization. Liquid carbon dioxide was metered manually into the settled water, dispersed through 1" PVC pipe drilled with small holes approximately 2 ft. apart. Baffles of polyethylene film were installed to prevent mixing back to the settling zone.

The purpose of the two stage carbonation is to first convert the hydroxide to carbonate alkalinity, precipitating calcium carbonate. For this reaction, the pH was held at 10.3.

---

*Magnesium sulfate was used as a make-up source of magnesium as no magnesium carbonate tri-hydrate was available at this time. The make-up dosage was quite low, less than 5 mg/l, thus, the noncarbonate hardness addition was minimal.

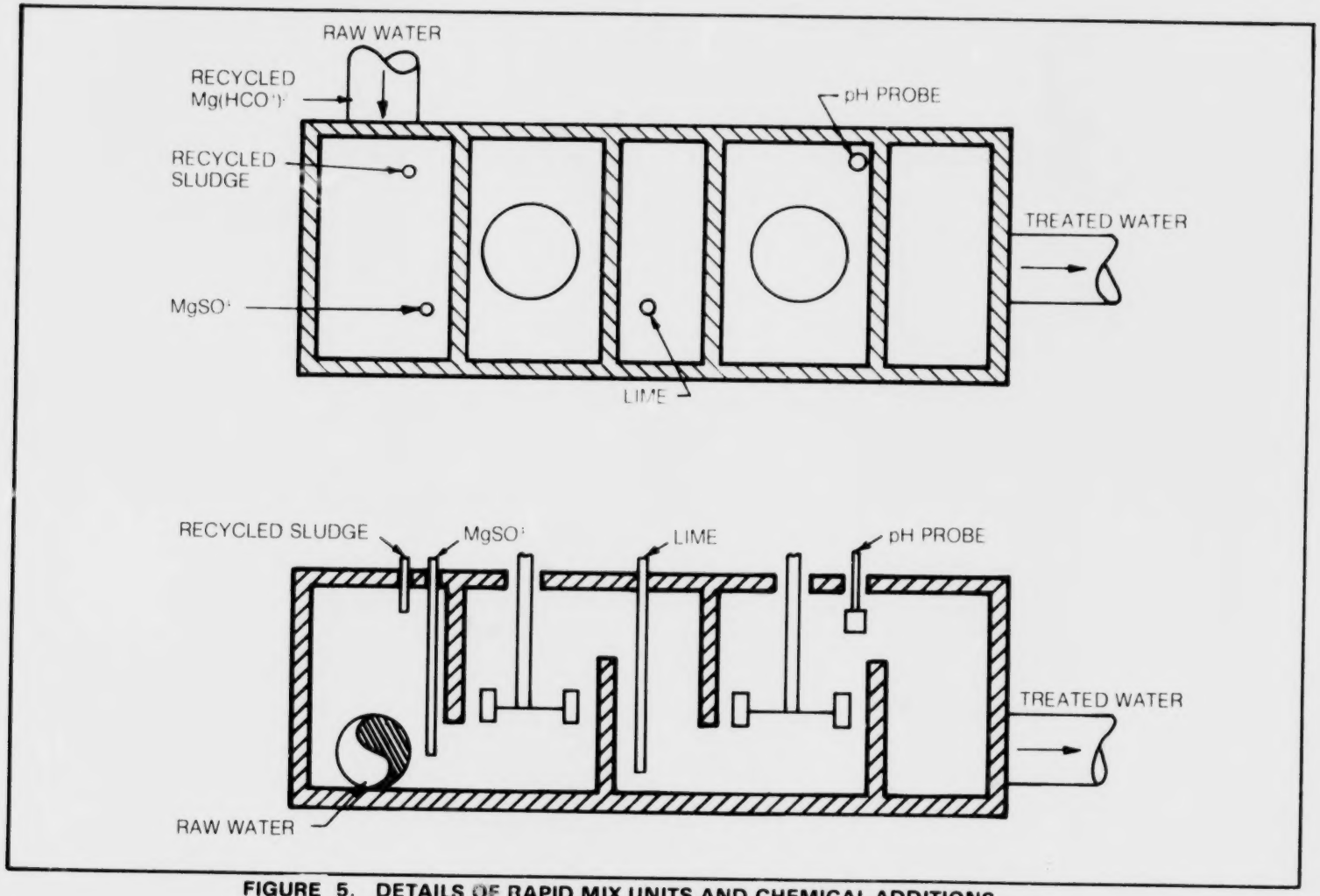


FIGURE 5. DETAILS OF RAPID MIX UNITS AND CHEMICAL ADDITIONS MONTGOMERY, ALABAMA

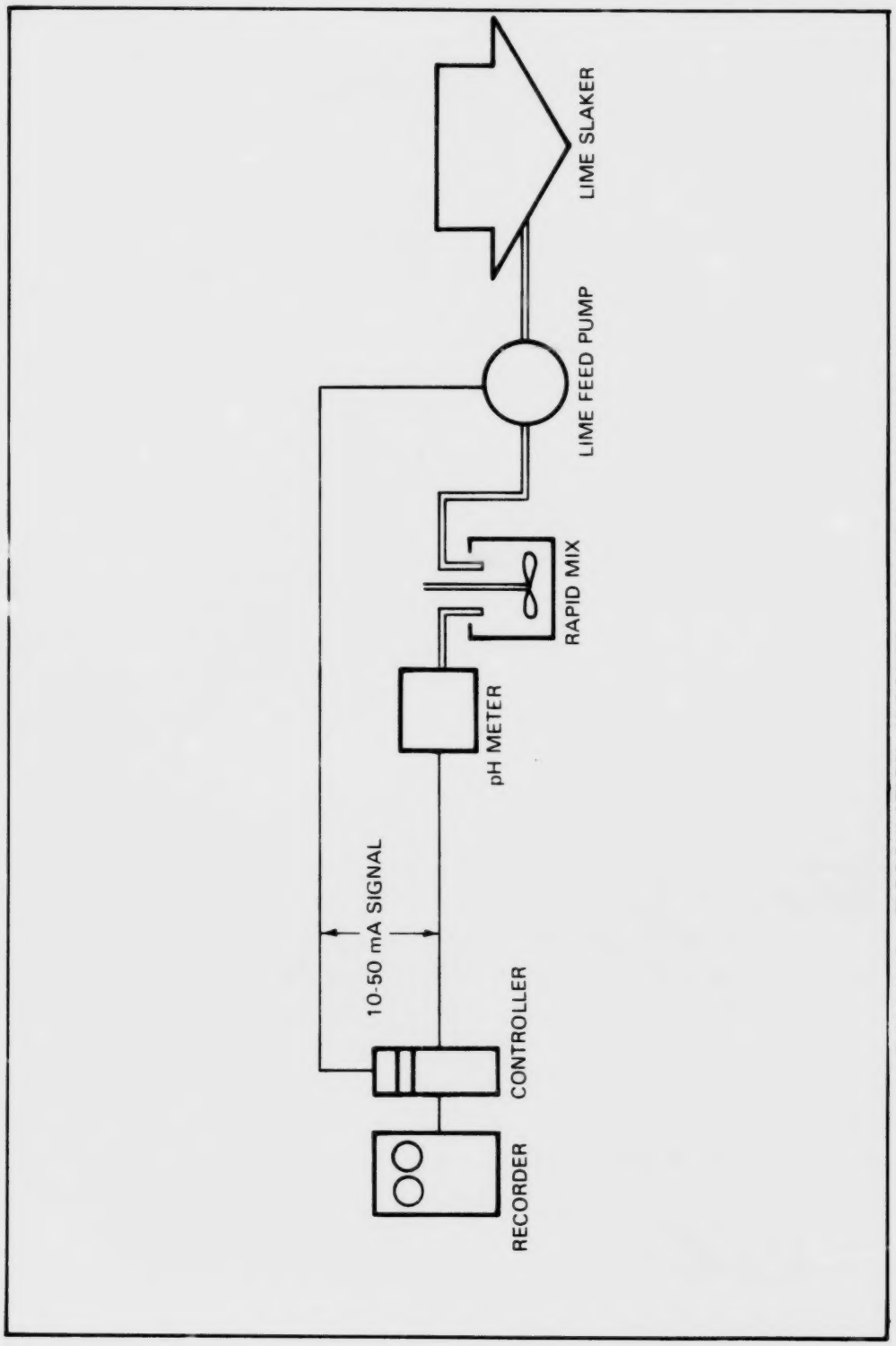


FIGURE 6. FLOCCULATION pH CONTROL SYSTEM - MONTGOMERY

Very little of the calcium carbonate formed settled, however, the solid phase is relatively stable and does not redissolve upon final pH stabilization just prior to filtration. The carryover of calcium carbonate onto the filter does not shorten the length of filter run and does not pass through the filter. Proper adjustment of the settled water pH prevents calcium carbonate from precipitating on the sand in the filter. Precipitated calcium carbonate carried onto the filter was easily removed on backwashing.

FILTRATION

Settled, stabilized waters from the alum and magnesium processes were separated and filtered in identical sand filters, generally at a rate of 1 to 2.5 gallons per square foot per minute. One of the four filters used on the magnesium process was converted to a dual media filter, replacing three inches of sand with anthracite having an effective size of 1.2 mm.

MAGNESIUM RECOVERY AND SLUDGE HANDLING

Figure 7 illustrates the units comprising the sludge recovery system. Sludge was pumped at a controlled rate into the carbonation cells using a variable speed Moyno pump. Four 10 cubic feet flotation cells were used for sludge carbonation. Again pure carbon dioxide was used, the feed being automated as shown in Figure 8. Carbonated sludge was pumped into a 10 feet diameter thickener with the overflow returned to the raw water using an intermediate 1800 gallon storage tank. The recycled magnesium bicarbonate was pumped at a controlled rate to give the desired coagulant dosage. The thickener underflow was vacuum filtered with a 3' X 3' drum filter*. The filtrate

*Envirotech Corporation, Salt Lake City, Utah

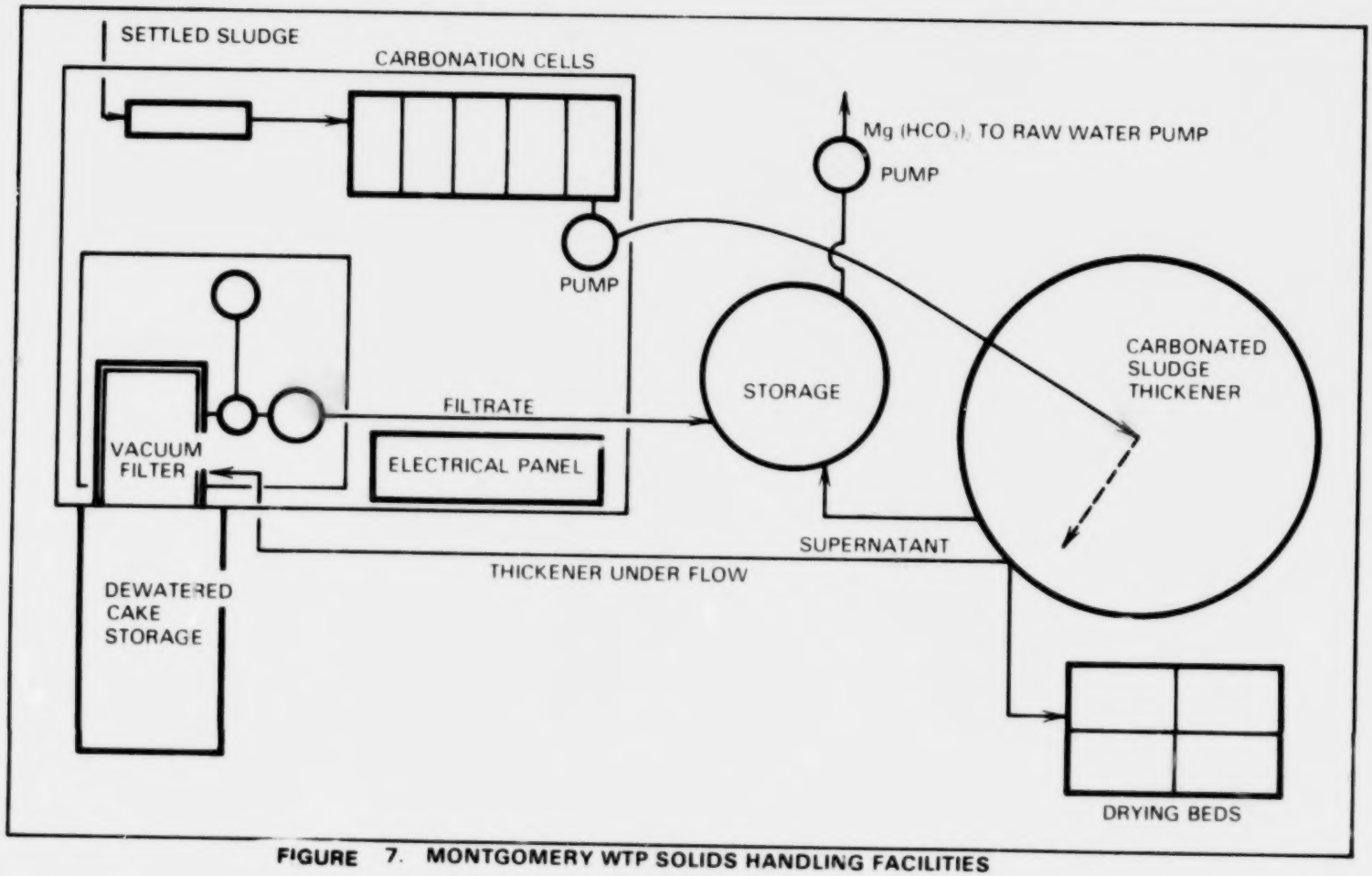


FIGURE 7. MONTGOMERY WTP SOLIDS HANDLING FACILITIES

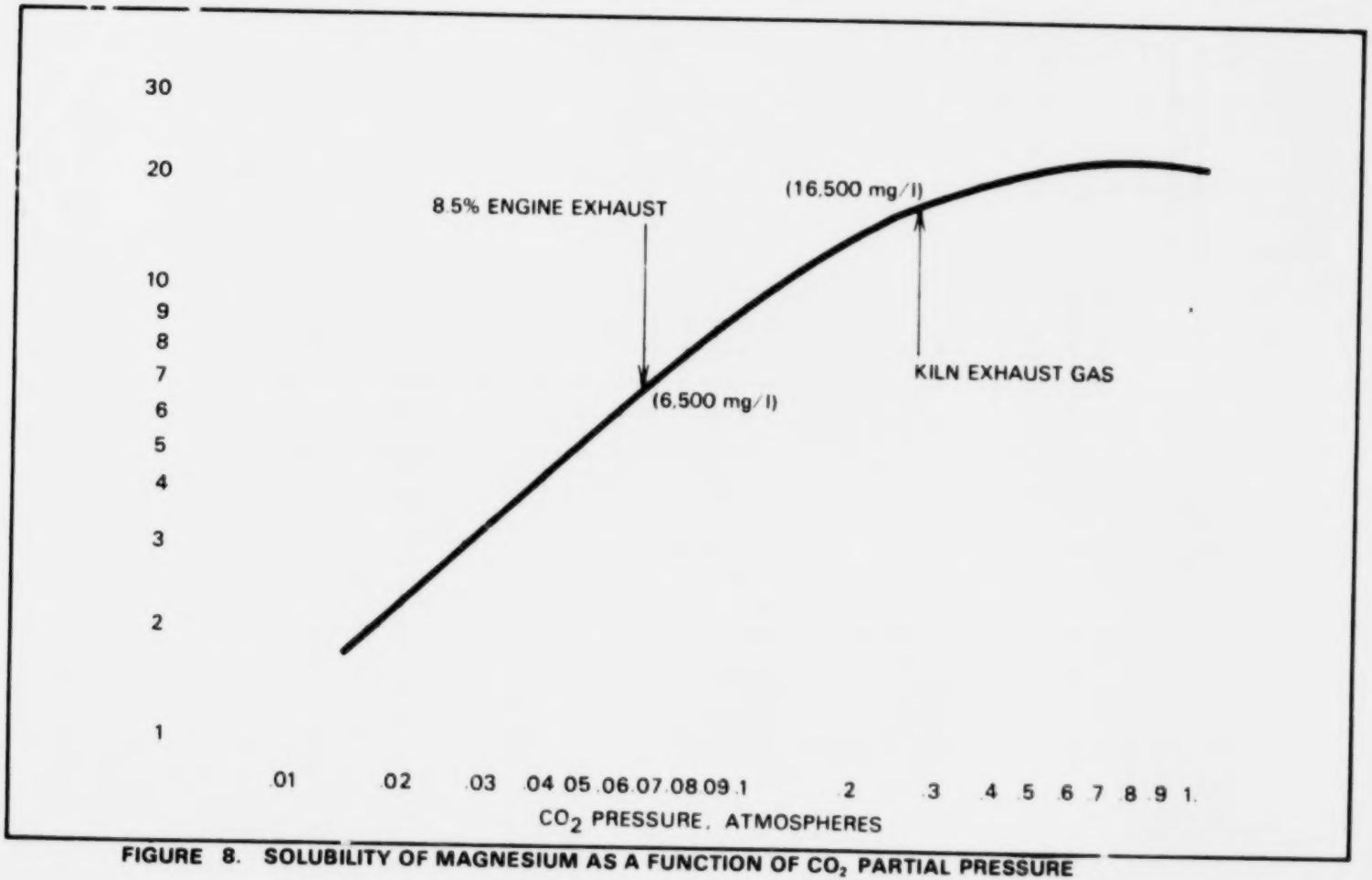


FIGURE 8. SOLUBILITY OF MAGNESIUM AS A FUNCTION OF CO_2 PARTIAL PRESSURE

was pumped to the magnesium bicarbonate storage tank and the filter cake hauled to a landfill.

There are several reasons why pure carbon dioxide should be considered for use in the smaller plants not recovering lime. The rate at which carbon dioxide solubilizes magnesium has been found to be first order with respect to the partial pressure of the carbon dioxide.[11] In addition, pure carbon dioxide will dissolve approximately 25,000 mg/l of magnesium bicarbonate, as shown in Figure 8, considerably more than the lower percentage carbon dioxide produced from on-site generation. The feed of liquid carbon dioxide is simpler, more flexible and easier to automate.

Carbon dioxide feed was automatically controlled to achieve a pH of 7.3, as shown in Figure 9. Near 100% efficiency is possible due to the very fine bubbles produced and the high driving force between the caustic sludge and the carbonic acid. At pH values below 7.3 the reaction has essentially gone to completion resulting in the loss of carbon dioxide to the atmosphere. The carbon dioxide bubbles cause foaming which is greatly accentuated by the slightly surface active organic color released from the sludge on carbonation. This foaming serves as a good indicator of excess carbonation and can be used for visual pH control of the process.

MELBOURNE FULL SCALE STUDIES

Both Montgomery and Melbourne presently use the conventional alum water treatment process; however, the raw waters treated vary drastically in chemical and physical characteristics. Table 5 illustrates typical ranges in raw water characteristics for Melbourne's Lake Washington water.

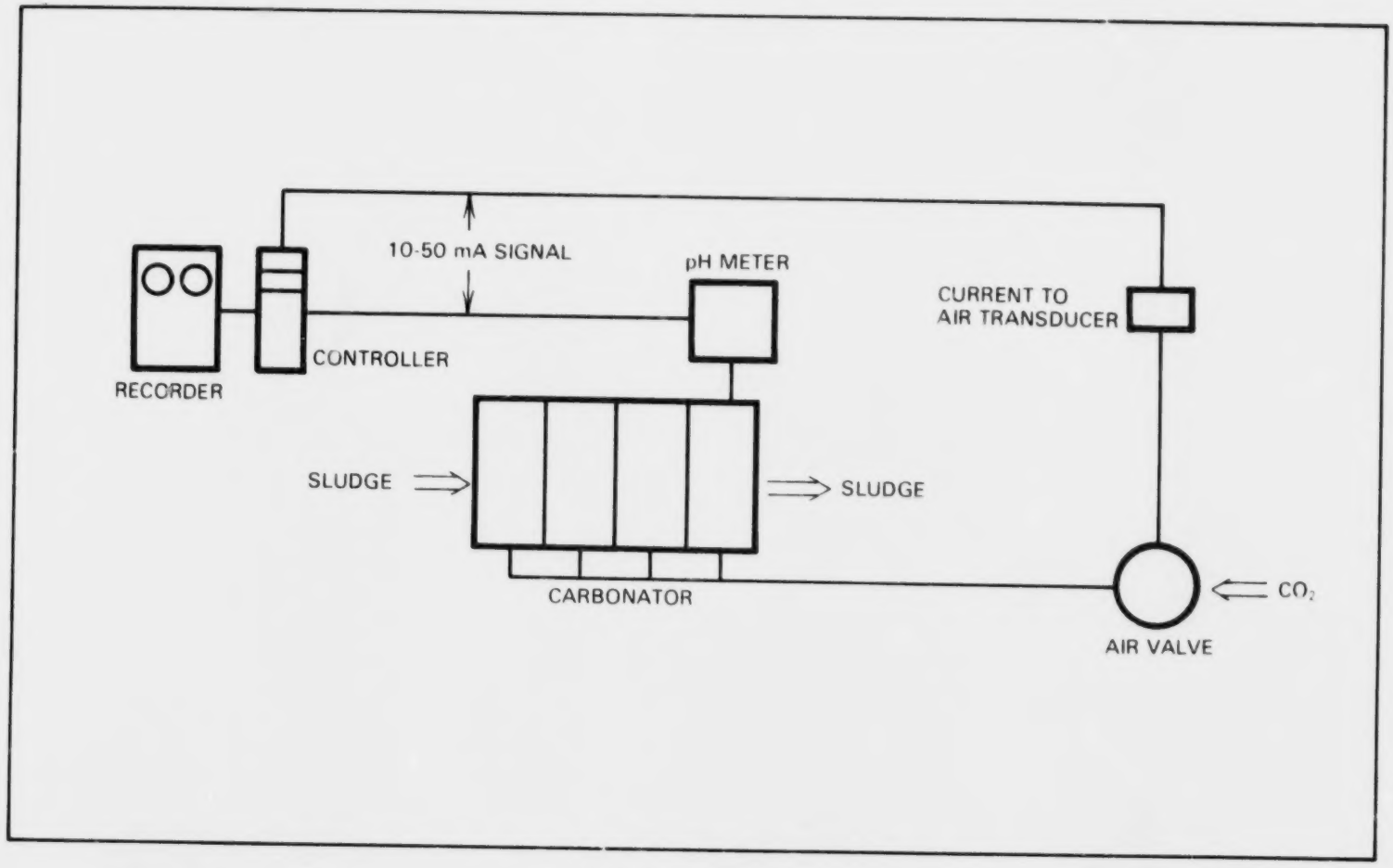


FIGURE 9. SLUDGE CARBONATION pH CONTROL SYSTEM - MONTGOMERY

TABLE 5. TYPICAL RANGE IN RAW WATER CHARACTERISTICS
LAKE WASHINGTON, MELBOURNE, FLORIDA

pH	Alkalinity (mg/l)	Hardness (mg/l) (As $CaCO_3$)	Magnesium (mg/l)	Color (mg/l) (Pt-Co)	Turbidity (mg/l) (JTU)
6.8-7.8	25-100	40-200	6-50	60-300	[a]

[a]Normally zero, but under severe storm conditions can increase to 30-50 JTU.

The chemical and physical characteristics of Lake Washington water are consistent on a daily basis. The water during the seasonal "dry" period is much harder and lower in organic color than during the "wet" season.

Montgomery typically uses from 20 to 30 mg/l of alum, coagulating in the pH range of 6.0 to 7.0. Melbourne uses as much as 130 mg/l of alum with coagulation in the pH range of 5.1 to 5.3. In addition, due to the high dissolved organics in the Melbourne water, high dosages of activated carbon are required along with large dosages of chlorine added to the finished water. Thus, while both plants would be termed "alum treatment plants", they represent different types of raw waters and treatment considerations.

PLANT PHYSICAL FACILITIES

Figure 10 is a layout of the Melbourne water plant converted to include the magnesium process in half of the plant. The Melbourne plant facilities differed from the Montgomery facilities primarily in that:

1. Vertical flocculators were used versus the Montgomery horizontal flocculators.
2. Upflow clarifiers designed for an overflow rate of .5 gallons/sq.ft./minute versus six (6) hour retention horizontal, settling basins in Montgomery.

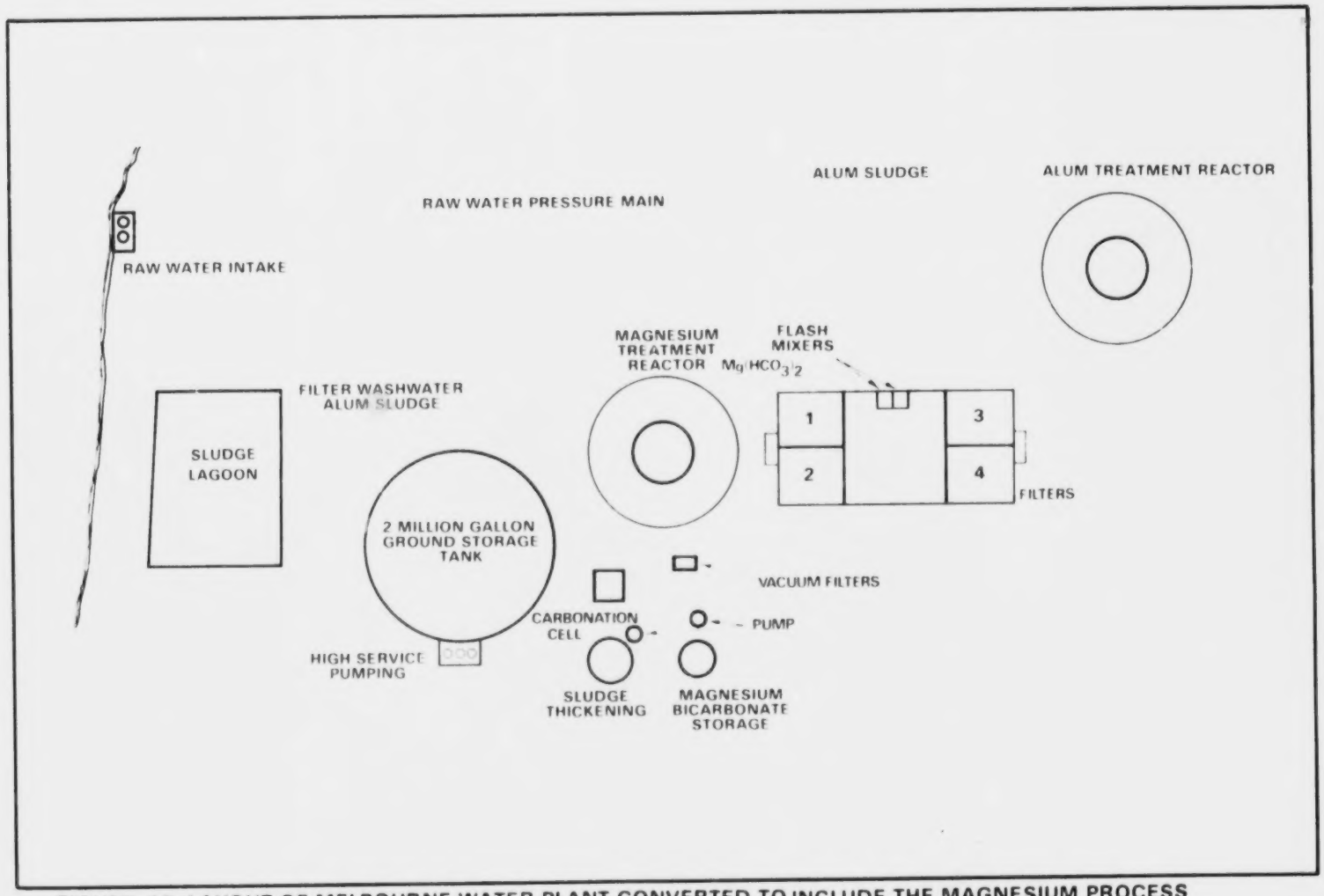


FIGURE 10. LAYOUT OF MELBOURNE WATER PLANT CONVERTED TO INCLUDE THE MAGNESIUM PROCESS

3. Manual feed of carbon dioxide and lime was provided at Melbourne.
4. Melbourne was provided with single stage finished water stabilization versus two stage stabilization at Montgomery.

The carbonation cells, thickener, recycle pumps, vacuum filter, and other miscellaneous equipment were shipped from Montgomery to Melbourne, so that little change was made in the magnesium recovery and recycle system. Melbourne's North Water Treatment Plant is constructed on a small hill. This elevation differential was used advantageously in the study to minimize pumping and to utilize gravity flow where possible.

A coagulant aid, either Dow AP30 or American Cyanamid 845A, both high molecular weight anionic polymers was added to the flocculator in very dilute solution. Typical dosages ranged from 0.1 to 0.3 mg/l.

PROJECT LIMITATIONS

The conversion of both plants was accomplished with a very limited budget on a temporary basis. This resulted in excessive mechanical down-time, particularly in Montgomery, and excessive labor requirements, generally in the early project stages.

In Melbourne, an unavoidable limitation was that 1973 was a "wet" year and the raw water hardness did not increase in the Fall as expected. Past records indicated that both a very soft, high-colored water and a hard, moderately-colored water would be treated during the project period. The "soft", highly-colored water treated during the entire project proved, as expected from previous laboratory studies, to be both the most challenging and expensive to treat. This

as important to the overall evaluation program since during dry years, such as 1971, the water is hard most of the year.

SECTION V

RESULTS AND DISCUSSIONS

PILOT PLANT STUDIES

Pilot studies were conducted in Montgomery, Alabama from November, 1971 until October 1972 using the facilities discussed in Section IV. Initial operation evaluated the use of liquid alum as a coagulant to compare the pilot plant performance with the full scale plant operation. It was found that only 10 gpm of raw water could be treated with alum without excessive floc carryover to the filters. These studies were conducted over a two week period.

The pilot plant system was thoroughly flushed and the magnesium process placed into operation. Operation was conducted initially on an intermittant daily basis; however, continuous operation was soon undertaken. Studies were initially undertaken for each of the various operations or processes involved, such as sludge carbonation, clarification, finished water stabilization, etc. Although all units were operating, data collection and special attention were given only to the specific process under study.

After each portion of the water treatment system had been studied and adjustments made as required, the pilot plant was operated as an integral system.

PILOT PLANT OPERATION

The pilot plant was typically operated treating raw water at the rate of 25 to 50 gpm. During normal daylight hours supervision was continuous. At night, water plant operators would hourly inspect the mechanical equipment, perform the necessary analyses and make the necessary chemical feed adjustments.

The sources and sinks of magnesium are extremely important in determining optimum process operating conditions. The sources of magnesium include the magnesium present in the raw water as well as any magnesium added. The sinks include magnesium losses in the dewatered sludge and magnesium present in the treated water. The magnesium loss in the finished water is largely affected by the pH of coagulation although finely divided magnesium hydroxide floc present as clarifier carryover will be dissolved on stabilization. The relationship between magnesium solubility as a function of pH is illustrated in Figure 11 for theoretical, jar test, and pilot plant conditions.

Table 6 illustrates typical data collected and operating conditions. Calcium carbonate turbidity, either carryover from clarification or formed during pH adjustment, was found to be completely removed by filtration without causing unduly short filter runs. In order to better evaluate process performance it was desirable to distinguish between true turbidity, the type found in the raw water, and calcium carbonate turbidity. This is referred to as acidified turbidity. Levels of less than 1.0 FTU were commonly experienced.

Table 7 illustrates the effect of drastically changed raw water quality on both the alum and magnesium process. At a constant magnesium dosage of 50 mg/l and coagulation pH of 11.3, the pilot plant produced a high quality product with almost no supervision. The alum process was upset by the change in raw water quality, even with constant supervision.

DISINFECTION STUDIES

The effect of high pH on bacterial and virus survival has been well documented by other investigations.[12,13,14] Limited studies were conducted to verify the effect of high pH

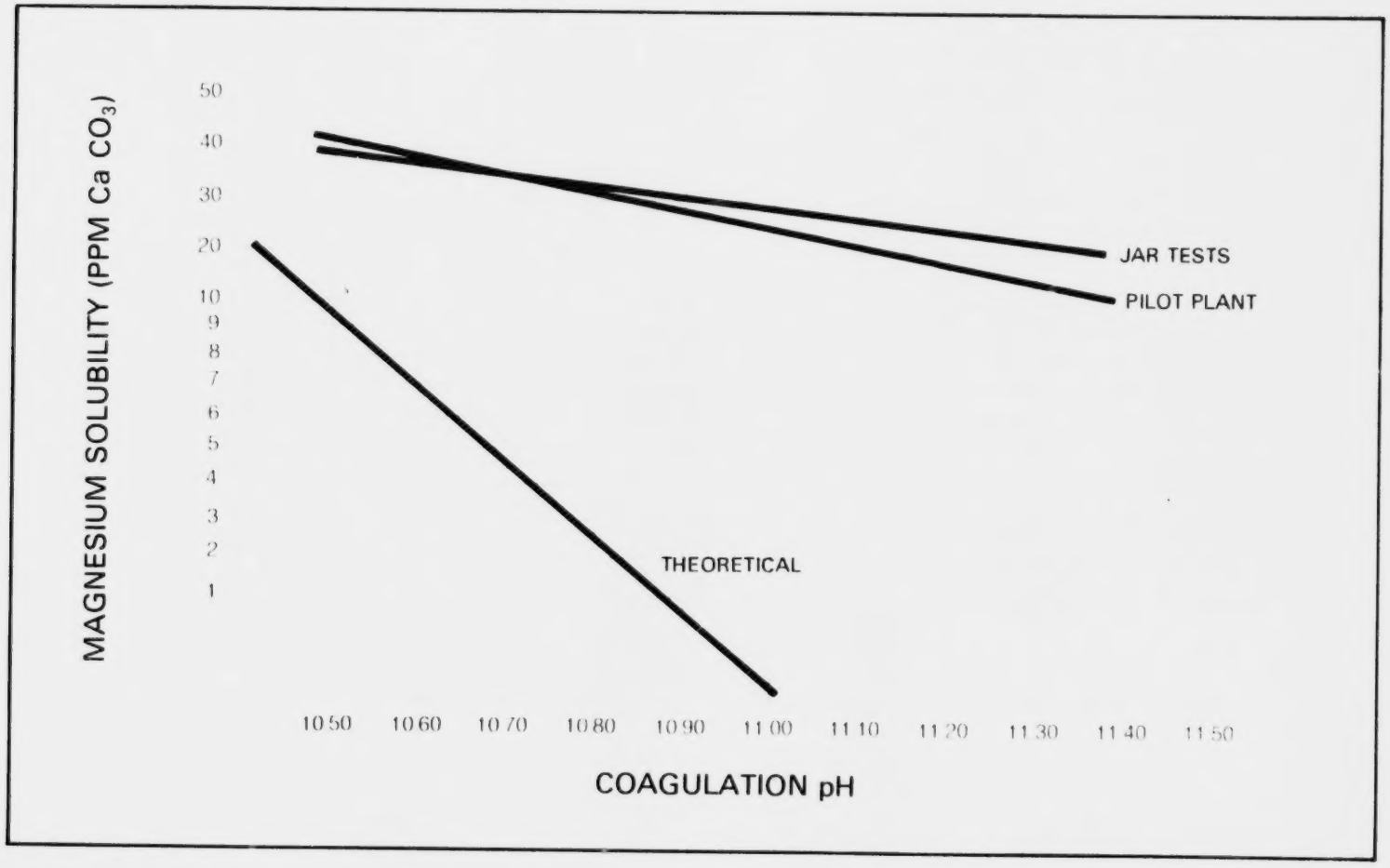


FIGURE 11. COMPARISON OF THEORETICAL SOLUBILITY OF $Mg(OH)_2$ WITH OBSERVED JAR TEST AND PILOT PLANT VALUES

TABLE 6. TYPICAL PILOT PLANT RESULTS

(Analyses performed each hour, averages shown)

Date/ Time	Raw Turbidity (FTU)	Coag-ulation pH	Carbonated Sludge pH	Stabilized Water					Filtered Magnesium			Filtered Alum Water Turbidity (FTU)
				pH	Turbidity (FTU)	Acid Turb. (FTU)	Alkalinity $CO_3^=$	Alkalinity HCO_3^-	Turb. (FTU)	Alkalinity $CO_3^=$	Alkalinity HCO_3^-	
8/14 1200		11.4		7.1	0.6	0.4	0	144				
1800	5.1	11.3	7.38	8.2	0.5	0.3	32	118	.08	0	121	.30
8/15 0030	4.7	11.3	7.16	7.9	0.6	0.4	0	107	.06	0	108	.24
0630	5.3	11.3	7.05	7.9	1.9	0.2	0	109	.05	0	101	.17
1200	3.5	11.3	7.10	9.0	0.8	0.5	32	117	.05	0	117	.05
1800	5.6	11.2	7.21	8.5	1.0	0.3	26	112	.05	0	110	.05
8/16 0000	4.7	11.3	7.91	7.9	0.6	0.3	0	92	.05	0	90	.07
0630	5.4	11.2	7.20	7.9	0.9	0.6	0	87	.06	0	85	.08
1200	4.9	11.3	7.28	8.2	--	1.0	56	87	--	0	97	.07
1800	4.3	11.1	6.21	8.4	--	2.3	20	89	--	12	94	.09
8/17 0000	4.6	11.0	7.5	7.5	--	1.3	0	77	--	0	82	.12
0600	5.2	11.1	7.4	7.7	--	0.8	16	66	.07	0	82	.09
1200	4.6	11.3	7.3	8.5	3.3	--	0	61	.08	0	60	.06
1800	5.0	11.3	7.2	8.8	5.8	--	19	63	.07	0	75	.06
8/18 0000	5.2	11.4	7.2	8.3	5.5	--	20	74	.06	0	81	.12
0630	3.9	11.4	7.4	7.7	6.5	--	0	81	.06	0	95	.05

TABLE 7. PILOT PL. T RESULTS DURING RAPID RAW WATER QUALITY DETERIORATION

(Analyses performed each hour, averages shown)

Date/ Time	Raw Turbidity (FTU)	Coag- ulated pH	Carbonated Sludge pH	Stabilized Water					Filtered Magnesium			Filtered Alum Water Turbidity (FTU)
				pH	Turbidity (FTU)	Acid Turb. (FTU)	Alkalinity $CO_3^=$	Alkalinity HCO_3^-	Turb. (FTU)	Alkalinity $CO_3^=$	Alkalinity HCO_3^-	
7/31												
1100	40	11.2	7.1	9.2	1.8	0.5	16	78	0.10	0	84	2.00
1300	32	11.2	7.2	9.2	1.5	0.5	24	74	---	12	74	---
1500	36	11.2	7.6	9.6	3.5	---	44	44	0.06	28	32	>3.00
1700	53	11.1	7.5	9.3	2.4	0.5	24	60	---	8	52	---
1900	75	11.1	7.4	8.4	1.5	0.4	8	68	0.05	4	68	>3.00
2100	200	11.1	7.5	7.5	1.4	---	0	76	---	0	82	---
2300	245	11.1	7.5	7.2	1.4	0.6	0	74	0.15	0	66	3.00
8/1												
100	--	11.2	7.5	7.3	1.3	---	0	68	---	0	76	---
300	--	11.2	7.5	7.3	1.4	0.5	0	76	---	0	70	---
500	--	11.2	7.5	9.5	3.0	---	45	48	0.10	0	72	2.80
700	55	11.2	7.5	9.5	2.0	1.0	46	48	---	28	28	---
900	55	11.3	7.4	9.8	3.2	---	64	38	---	28	36	---
1100	50	11.0	7.4	9.7	2.8	---	52	38	0.22	32	38	2.00
1300	45	10.7	7.3	7.7	1.4	0.3	0	82	0.31	10	78	---
1500	--	10.7	7.3	7.4	1.0	1.0	0	76	0.28	0	85	1.00
1700	40	10.7	7.4	7.2	1.7	---	0	82	---	0	92	---
1900	40	10.7	7.4	7.3	3.9	1.5	0	74	0.40	0	84	---
2100	40	10.9	9.8	7.2	2.7	1.6	0	72	---	0	78	---
2300	54	11.0	10.4	7.1	3.0	1.2	0	74	0.30	0	78	1.00

on coliform survival. In general, these studies consisted of adding various $Ca(OH)_2$ dosages to 1 liter jars of raw water to obtain a pH range of 10.5 to 11.7. Samples were collected from each jar at predetermined time intervals and analyzed for total coliform organisms. A summary of these laboratory studies is shown in Figure 12. Table 8 includes all laboratory coliform disinfection experiments.

The raw water source for the pilot plant was obtained prior to pre-chlorination. When operating at 50 gpm a hydraulic retention time of approximately two hours allowed complete disinfection of coliform organisms when coagulation at a pH above 11.0.

It should be pointed out that while the high pH is effective, it is not nearly as effective as free chlorine at the normal pH range of raw water. A pre-chlorine dosage of 1.5 mg/l resulted in complete disinfection with less than a 30 second contact time.

SOLIDS HANDLING

This section of the report will be limited to sludge thickening and vacuum filtration. The pilot plant was used to generate sufficient solids for a thorough laboratory evaluation to develop design criteria and predict process performance.

Considerable data exists for thickening and filtering pure calcium carbonate slurries; however, data for clay-calcium carbonate slurries are limited. The higher the percentage of calcium carbonate present the more readily the sludge thickens and dewaters. The characteristics of the Montgomery raw water are such that the only calcium carbonate produced results from the recycle of magnesium bicarbonate. The ratio of calcium carbonate to clay will vary from summer to winter months as the turbidity in the raw water changes. The sludge produced in the treatment of Montgomery's water should represent the most difficult situation to be encountered.

TABLE 8. SUMMARY OF COLIFORM SURVIVAL LABORATORY STUDIES

Lab Studies - Montgomery, Alabama
(total coliform per 100 m.l.)

	pH								
Time (min.)	10.6	10.8	10.9	10.95	11.2	11.3	11.4	11.45	11.5
0	900	400	900	400	400	900	1100	800	1100
3								560	
5		400			200		300		700
6								360	
10							350	190	100
11		150		100	100				
13	350		100			50			
15							250		150
20	80		60	20	20	20	100	65	
30									20
40	15		5	0	0	0		18	
60							5		0
80	3		0						

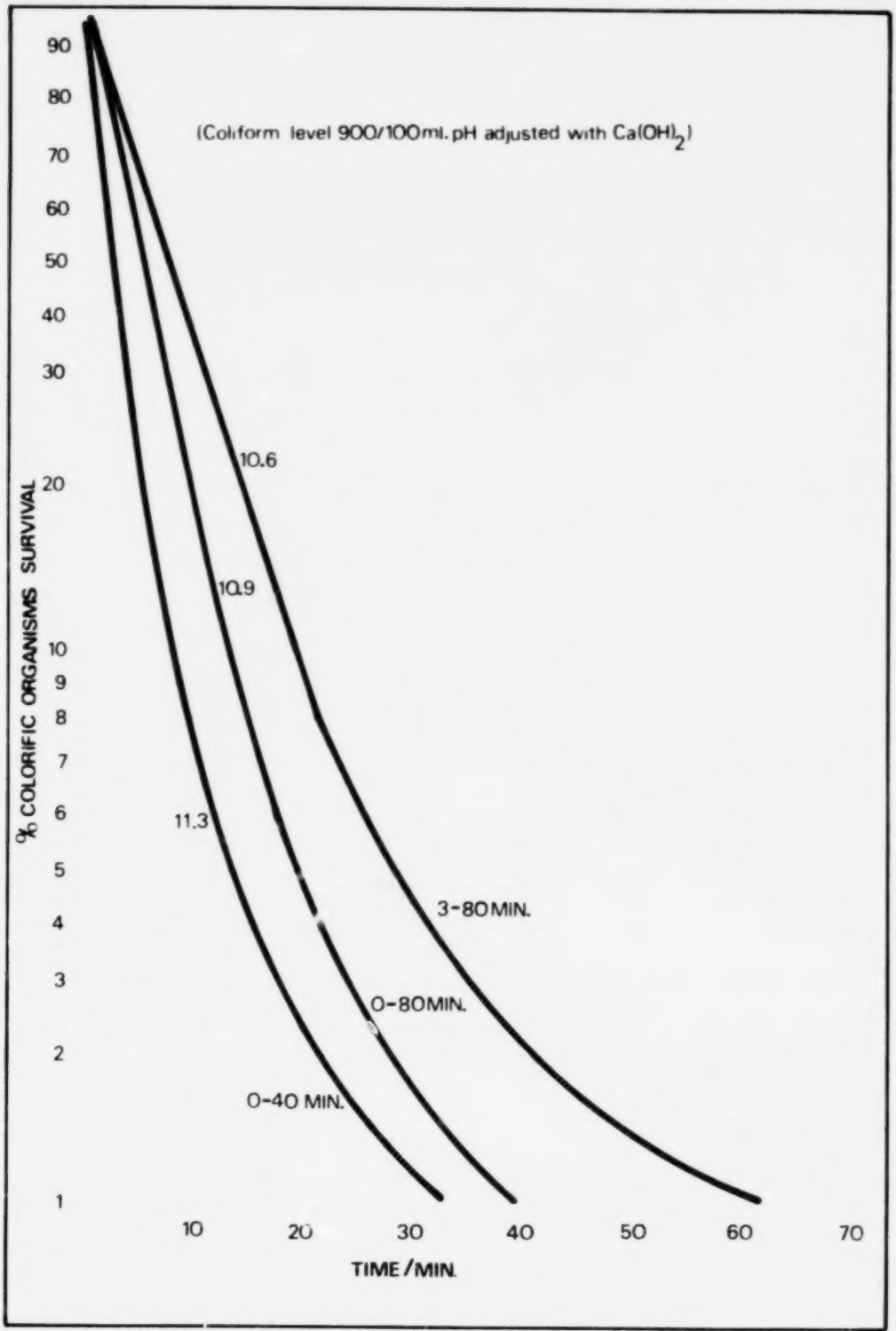


FIGURE 12. EFFECT OF pH ON COLIFORM SURVIVAL LABORATORY STUDIES

A number of bench scale thickening studies were performed during the pilot plant study. Figure 13 illustrates the relative differences between the thickening characteristics of the alum sludge and the carbonated pilot plant sludge.

The uncarbonated sludge thickened to a lesser degree due to the magnesium hydroxide present. The sludge concentration from the clarifier, however, exceeded 15% solids during most of the study period.

Leaf filter tests were run to determine design criteria for the full scale vacuum filter. A number of cloths were evaluated and a multi-filament, polypropylene, high air flow rate cloth was found most effective in producing a clear filtrate, high cake yield, and relatively clean cake discharge. Figure 14 summarizes a number of leaf filter tests and illustrates the effect of feed solids concentration on the filtration rate. During this study period, the sludge was composed of 70% calcium carbonate, 25% clay or inert content, and 5% magnesium hydroxide.

The thickener and vacuum filter design are obviously related. Each situation dictates an optimum design to minimize costs and labor requirements.

COLOR REMOVAL STUDIES

Organic color release upon carbonation will not present a problem for the application of the magnesium process in Montgomery. However, for the more highly colored waters and in the treatment of certain colored industrial wastes, this could become a significant problem. Water plants treating high magnesium waters, producing magnesium carbonate as a by-product, also present a problem with the coloring of the magnesium carbonate. Thus, color removal prior to magnesium carbonate precipitation would increase the quality of the product. For these reasons, decolor-

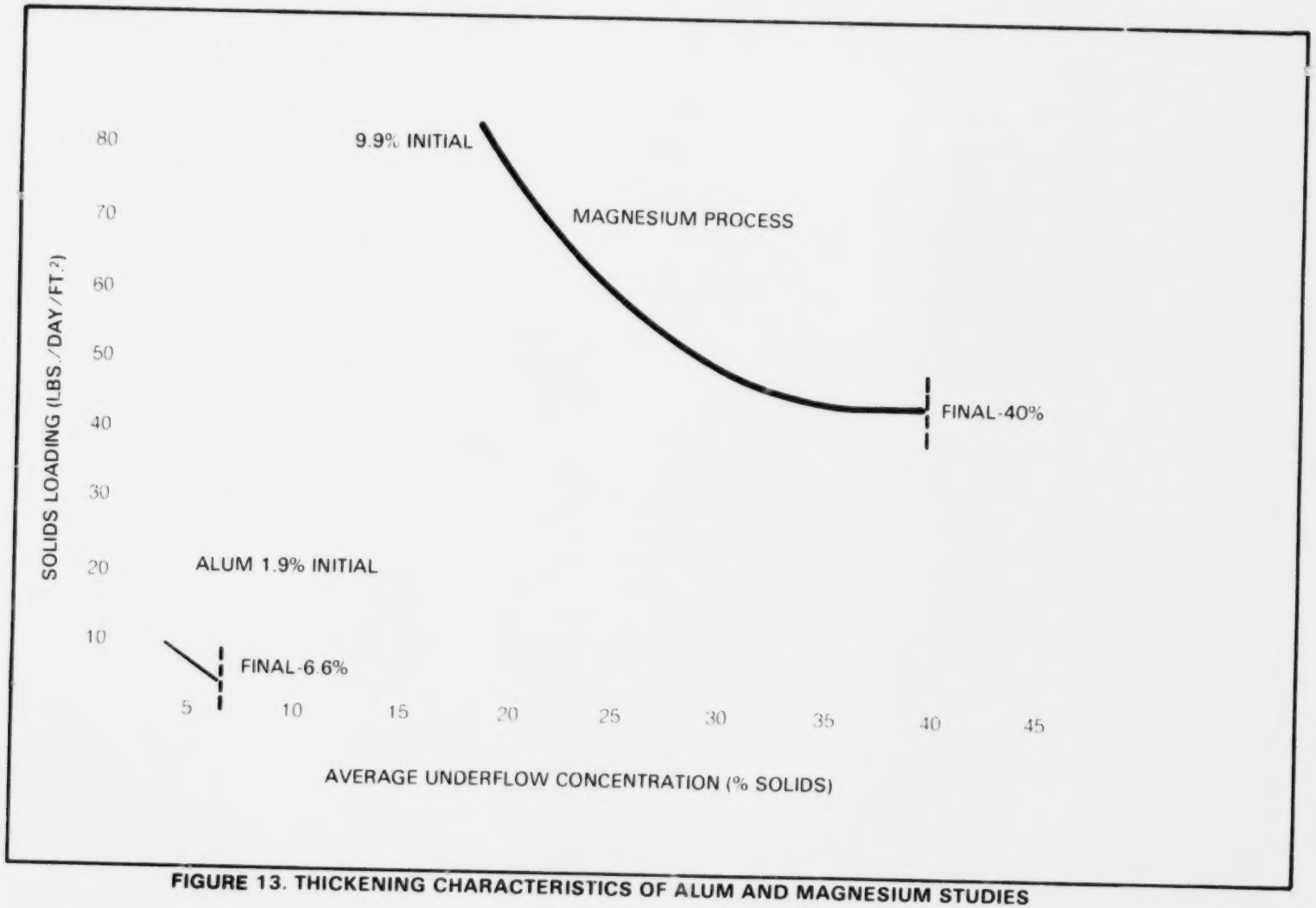


FIGURE 13. THICKENING CHARACTERISTICS OF ALUM AND MAGNESIUM STUDIES

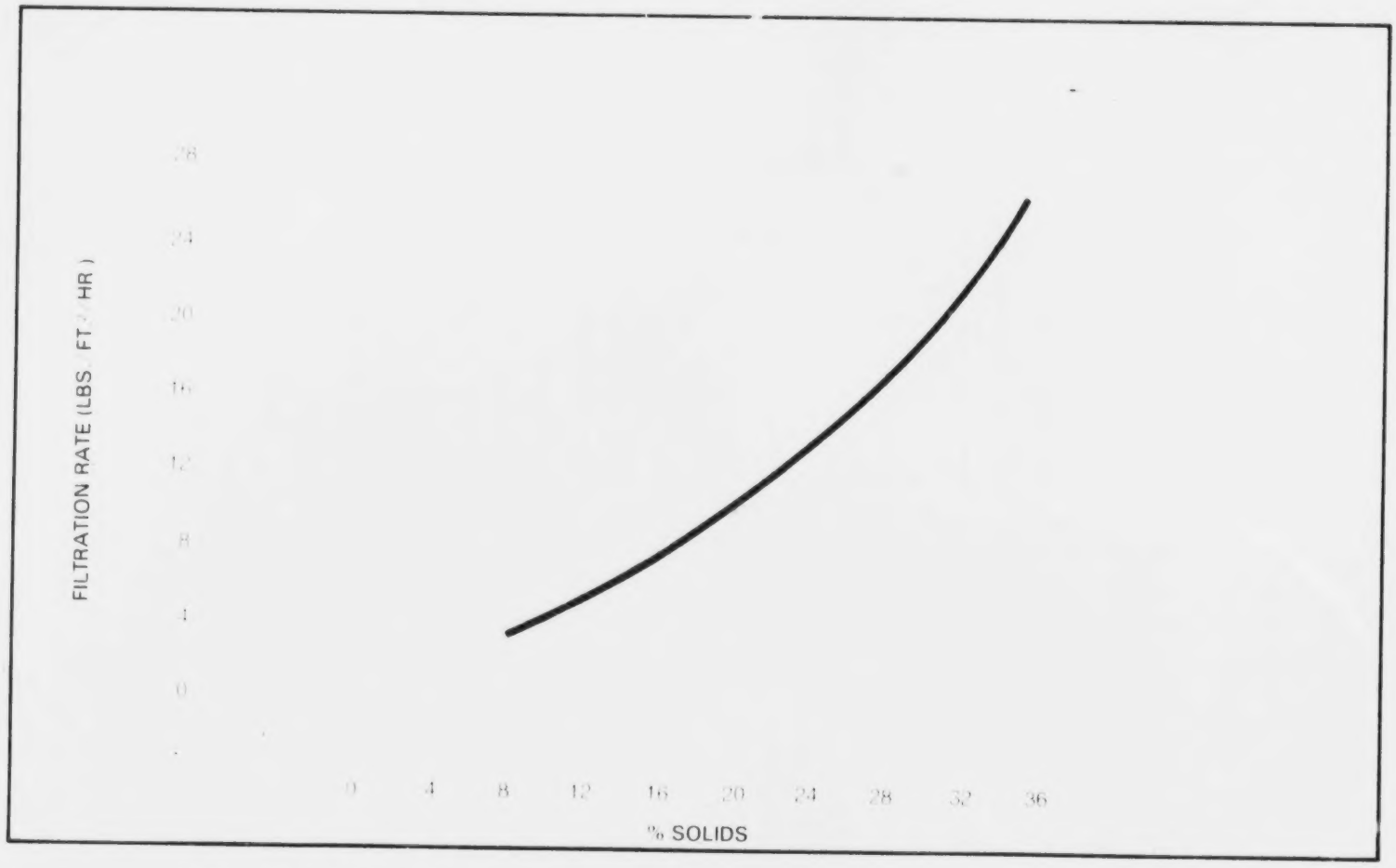


FIGURE 14. % SLUDGE SOLIDS VERSUS VACUUM FILTER RATE - MONTGOMERY

ization of the magnesium bicarbonate solution was studied using activated carbon.

Powdered FILTRASORB #400 carbon (by Pittsburg Activated Carbon) was used in this study. The studies were conducted on a batch basis maintaining constant temperature by means of a water bath. Average magnesium bicarbonate concontrations of 6,000 mg/l as calcium carbonate were present in the solution tested with no magnesium reduction found as a result of the color adsorption. The resulting data were plotted using the Fruendlich isotherm equation, $X/M = KC^{1/n}$, to obtain the adsorptive capacity. Tables 9 and 10 show the data obtained in two such experiments and are plotted in Figure 15. The only variable in these two experiments was temperature.

At a temperature of 35°C, 1 gram of carbon would completely decolorize 3,600 ml of solution while at 22°C, 1 gram would only decolorize 1,200 ml. Based on the 35°C figure a cost of approximately $2 per million gallons of water treated is estimated for carbon adsorption to remove the color found in the recycled coagulant liquor in this study. These costs are only crude estimates for the Montgomery water and cannot be used for waters in general. It would seem that carbon adsorption may represent an economical solution where color release is a problem.

Chlorine was also investigated as a means of decolorizing the recycled magnesium solution. As shown in Table 11, the chlorine was also very effective.

Samples (100 ml) of the recycled solution were dosed with chlorine stock solution to give the desired treatment levels. After sixty minutes the samples were filtered and color determined. Calcium hypochlorite was used as a chlorine source.

TABLE 9. CARBON ADSORPTION OF RELEASED ORGANIC COLOR
(Temperature = 22°C, 200 ml of solution used
and contact time of 20 minutes)

(M) Carbon (grams)	(C) Residual Color	(X) Adsorbed Color (grams)	X/M
Blank	550	0	
.1	282	268	2680
.2	124	436	2180
.3	68	482	1606
.4	36	514	1285
.5	23	527	1054

TABLE 10. CARBON ADSORPTION OF RELEASED ORGANIC COLOR
(Temperature = 35°C, 200 ml of solution used)

(M) Carbon (grams)	(C) Residual Color	(X) Adsorbed Color (grams)	X/M
Blank	425	0	
.1	130	295	2950
.2	91	334	1670
.3	50	375	1250
.4	38	387	967
.5	33	392	784

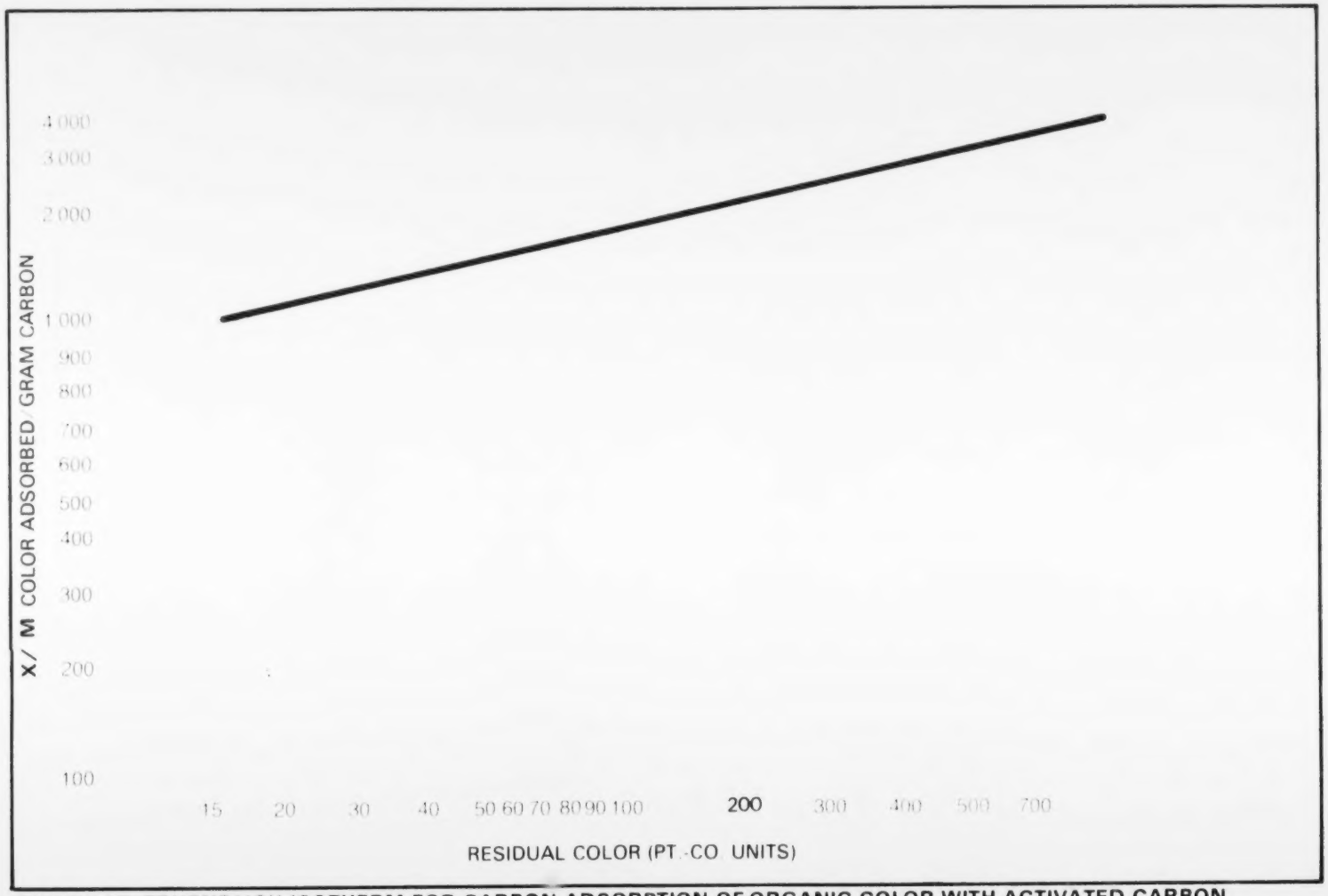


FIGURE 15. FRUENDLICH ISOTHERM FOR CARBON ADSORPTION OF ORGANIC COLOR WITH ACTIVATED CARBON

TABLE 11. USE OF CHLORINE TO REDUCE ORGANIC COLOR

Chlorine (mg/l)	Original Color (Pt-Co)	Residual Color (after 60 minutes)	% Removal
50	647	202	69
100	616	103	83
150	591	63	90
200	566	55	91
250	544	53	91

CADMIUM STUDY

The effectiveness of this new process in the removal of heavy metals was studied in both jar tests and in the pilot plant. Cadmium was chosen because of its easy and accurate determination by atomic adsorption as well as for the fact that it would likely be solubilized at a pH of 7.0, the pH of sludge carbonation. The results of jar tests are shown in Tables 12, 13 and 14.

TABLE 12. EFFECTIVENESS OF ALUM IN REMOVING CADMIUM

Alum Dosage (ppm)	Cadmium Residual (mg/l)
5	1.04
7	1.09
9	1.09
11	1.10
13	1.07

Initial cadmium level - 1.1 mg/l
Comments - Good floc formed in all jars

TABLE 13. EFFECTIVENESS OF LIME IN REMOVING CADMIUM FROM WATER IN JAR TESTS[a]

Lime Dosage (ppm)	pH	Cadmium Residual (mg/l)
40	10.65	0.73
50	10.70	0.81
60	10.95	0.72
80	11.10	0.71
100	11.25	0.60
120	11.30	0.60

[a]1.0 mg/l cadmium present in raw water.

TABLE 14. EFFECTIVENESS OF MAGNESIUM HYDROXIDE IN REMOVING CADMIUM FROM WATER IN JAR TESTS

Magnesium Precipitated (mg/l)	Cadmium Residual (mg/l)	% Removal
2.9	.36	58
7.5	.15	82
13.4	.05	94
21.4	.02	98
31.4	.01	99
42.2	.01	99

Reagent grade cadmium chloride was used as a source of cadmium in all studies. Samples taken after settling were filtered through Whatman #40 paper prior to analysis. Unfiltered samples taken during the study reported in Table 15 showed similar removals.

During pilot plant studies cadmium chloride was added continously to the raw water for a period of ten days. The magnesium and lime dosage was 40 and 100 mg/l respectively. The raw water cadmium level ranged from 0.75 to 1.0 mg/l. The settled water ranged from 0.003 to 0.007 mg/l and the filtered water ranged from 0.000 to 0.005 mg/l of cadmium. Table 14 summarizes the analytical results.

Cadmium was not released in any appreciable amounts on carbonation regardless of the pH to which carbonation was carried. A pH range of 6.8 to 7.7 generally resulted in a cadmium concentration of 0.1 mg/l or less in the recycled magnesium bicarbonate solution.

FILTRATION STUDIES

Two identical 1.5 square foot pilot filters with continuous turbidity monitoring equipment were made available to the project by the Taulman Company, Atlanta, Georgia. Combinations of sand and various sized anthracite media were evaluated as to water quality produced and operating characteristics. Initial studies compared the filterability of the alum treated water, piped from the full scale plant, with the stabilized magnesium treated water. Later studies were made using the proper stabilization pH, type media, and depths of sand anthracite required.

These studies allowed the following conclusions:

1) Filtration efficiency is directly related to

TABLE 15. PILOT PLANT RESULTS - CADMIUM STUDY

(Cadmium concentration - ppm mg/l)

Date/ Time	Raw Water	Carbonate Sludge	Clarified Water	Filtered Water
7/20:				
1400	0.92	--	--	--
1600	0.75	--	--	--
7/21:				
0930	0.94	--	0.005	0.005
1300	1.00	--	0.007	0.005
1510	0.78	--	0.003	0.000
7/25:				
1300	0.80	--	0.030	0.00
1500	0.81	--	0.030	0.00
1610	0.82	--	--	0.00
7/26:				
0830	0.55	0.12	0.030	0.00
1320	0.60	--	0.060	0.003
1530	--	0.12	--	0.005
7/27:				
0930	0.87	0.14	0.060	--
1415	--	0.16	0.050	--
1540	0.90	0.10	0.030	--
7/28	--	0.05	--	--

coagulation and clarification efficiency for both the alum and magnesium process. When proper pretreatment has not been accomplished, filtration will not provide adequate treatment.

2) The carryover of calcium carbonate will not shorten filter runs or reduce the quality of the filtered water.

3) In Montgomery, filtration of waters which had not been stabilized below pH 9.0 resulted in calcium carbonate precipitation on the anthracite and sand media. Precipitation occurred more rapidly and extensively on the sand. Extremely short filter runs were obtained under these conditions and the calcium carbonate formed could not be washed from the filter. These "balls" gradually worked their way into the gravel underdrain, eventually requiring acidification treatment of the filter. These studies provided a severe warning as to the necessity of adequately maintaining the proper stabilization pH in full scale operation.

4) Maximum filter runs were obtained with four inches of 1.2 mm anthracite media over twenty-four inches of standard filter sand. Increase in anthracite media depth did not increase filter performance either in length of filter run or water quality produced.

5) In general, two filter rates were studied, 2 and 3.5 gal./sq.ft./min. The higher rate on the average produced a slightly better water quality. It appeared that backwash requirements were essentially the same, based on percentage of the water

produced during the run.

6) The geometry of the pilot filters was such that backwashing was not equivalent to the full scale filters. Side wall friction was considerably higher, resulting in an unusual backwash pattern. Considerable care was required to prevent backwashing of media from the system. Backwash rates of 15 gal./sq.ft./min were not possible, so that some of the calcium found on the media could possibly have been removed at higher backwash rates.

7) Finished water stabilization appears to enhance filtration efficiency. Clarifier turbidity carryover serves as a nucleus for calcium carbonate precipitation, enlarging the particle size and changing the chemical-physical properties, increasing the opportunity for removal by filtration.

8) Calcium carbonate carryover to the filters does not shorten filter runs and can be easily removed on backwash. Calcium carbonate precipitation on the filter media drastically shortens filter runs and cannot be removed efficiently by backwashing.

MONTGOMERY FULL SCALE STUDIES

From November 1972 until June 1973 full scale evaluation of the Magnesium Process was conducted in Montgomery. The Magnesium Process was found to compare favorably with the alum process in both overall operation and water quality produced.

During the study voluminous data were collected at many points of the process. Figure 16 illustrates a summary of process control points and a brief discussion as to

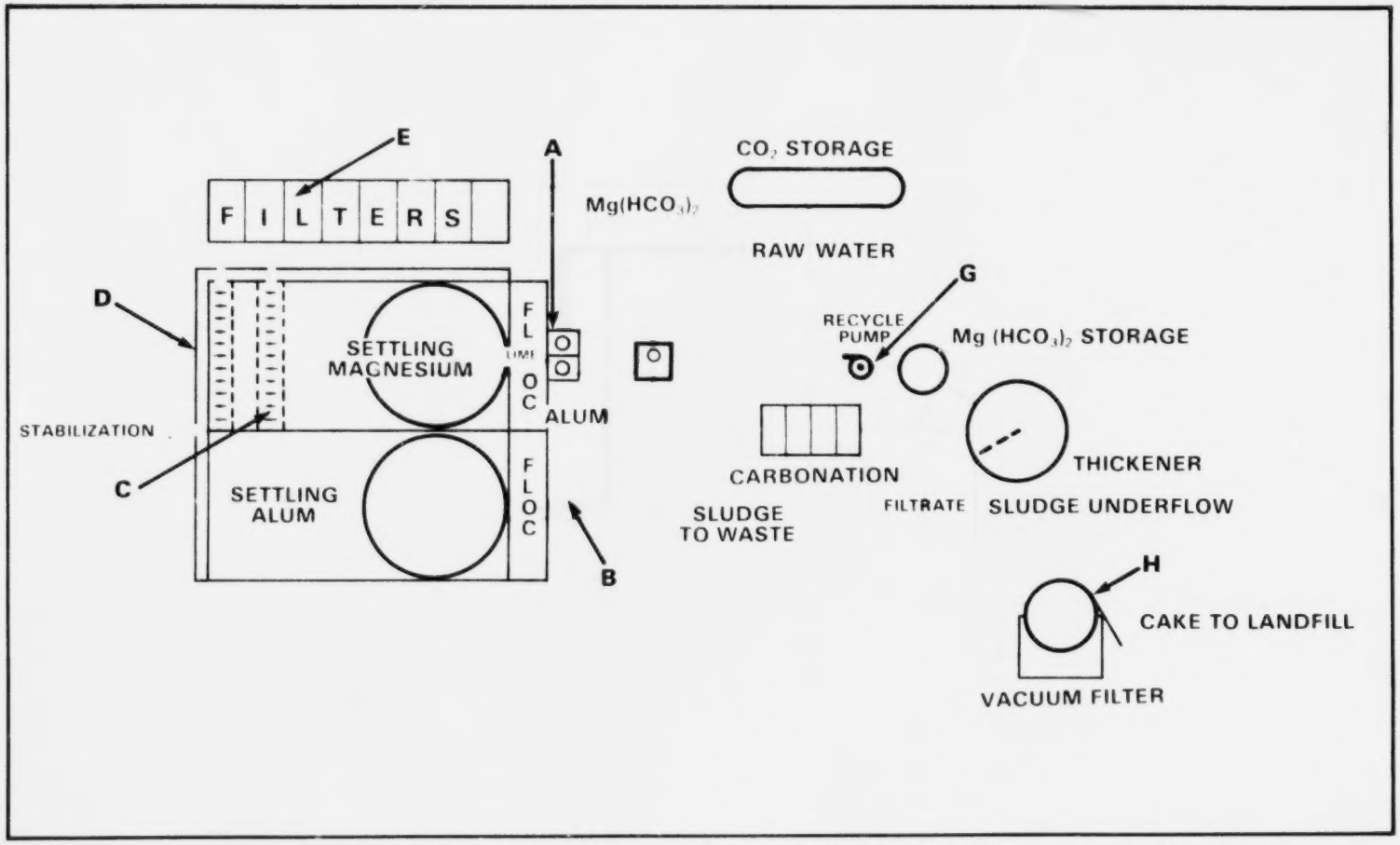


FIGURE 16. PROCESS CONTROL POINTS AND SAMPLING LOCATIONS – MONTGOMERY

which tests were performed are listed in Table 16. Data sheets to illustrate typical results are included in the Appendices under Appendix A.

The full scale studies found the magnesium coagulation system to be much more stable than the alum system, particularly in the coagulation process. Under certain raw water conditions, the alum coagulation pH must be maintained within $\pm$ 0.1 pH unit in order to treat the water satifactorily. Slight variance from the optimum pH results in greatly decreased coagulation efficiency. The low alkalinity water used by Montgomery has a very poor buffer capacity, particularly after the addition of alum when the alkalinity is seldom above 1 mg/l as $CaCO_3$. Slight changes in either pre-lime or alum feed can affect the coagulation pH to a large degree.

Automation of the lime feed and carbon dioxide feed for sludge carbonation proved to be very satisfactory. Control of both feeds are such that less than 0.1 pH from the desired pH occurs.

Recovery of magnesium as the bicarbonate was routinely carried out at a constant rate sufficient to provide the average coagulation requirements. When raw water conditions required additional magnesium feed, make-up magnesium sulfate was fed. After feeding make-up magnesium for a period of approximately twenty-four hours, increased magnesium content in the recovered solution eliminated the need for make-up magnesium.

Figure 17 illustrates the relationship between raw and settled turbidity as a function of time and magnesium dosage. These results indicate an important point. As the operators became more familiar with the process, a significant improvement in treatment efficiency was noted.

Figure 18 shows the total and magnesium hardness of the Montgomery stabilized water as a function of

TABLE 16. CONTROL SYSTEMS AND SAMPLING LOCATION

A) Rapid Mixer #1. Total and calcium hardness were determined on a filtered sample from which the magnesium feed could be determined.

B) Rapid Mixer #2. Automatic pH control of lime feed.

C) Carbonation Point 1. pH measurement and manual control of CO_2 rotameter to maintain a pH of 10.3. When the pH is too low or too high, the water is clear indicating that calcium carbonate precipitation is not taking place.

D) Settled magnesium water flume. pH, turbidity, total hardness, calcium hardness, alkalinities, and acid turbidity were determined on a routine basis.

E) Filtered magnesium treated water - continuous turbidity monitoring along with alkalinities, pH, and hardness determined on a routine basis.

F) Carbonated Sludge - Automatic pH control of the carbon dioxide flow along with alkalinity titrations on a routine basis.

G) Recycled magnesium control system - alkalinities measurement and flow control.

H) Vacuum filter - filter rates, solids inflow, filtrate alkalinities, filter cake solids, and filter cake composition are determined on a routine basis.

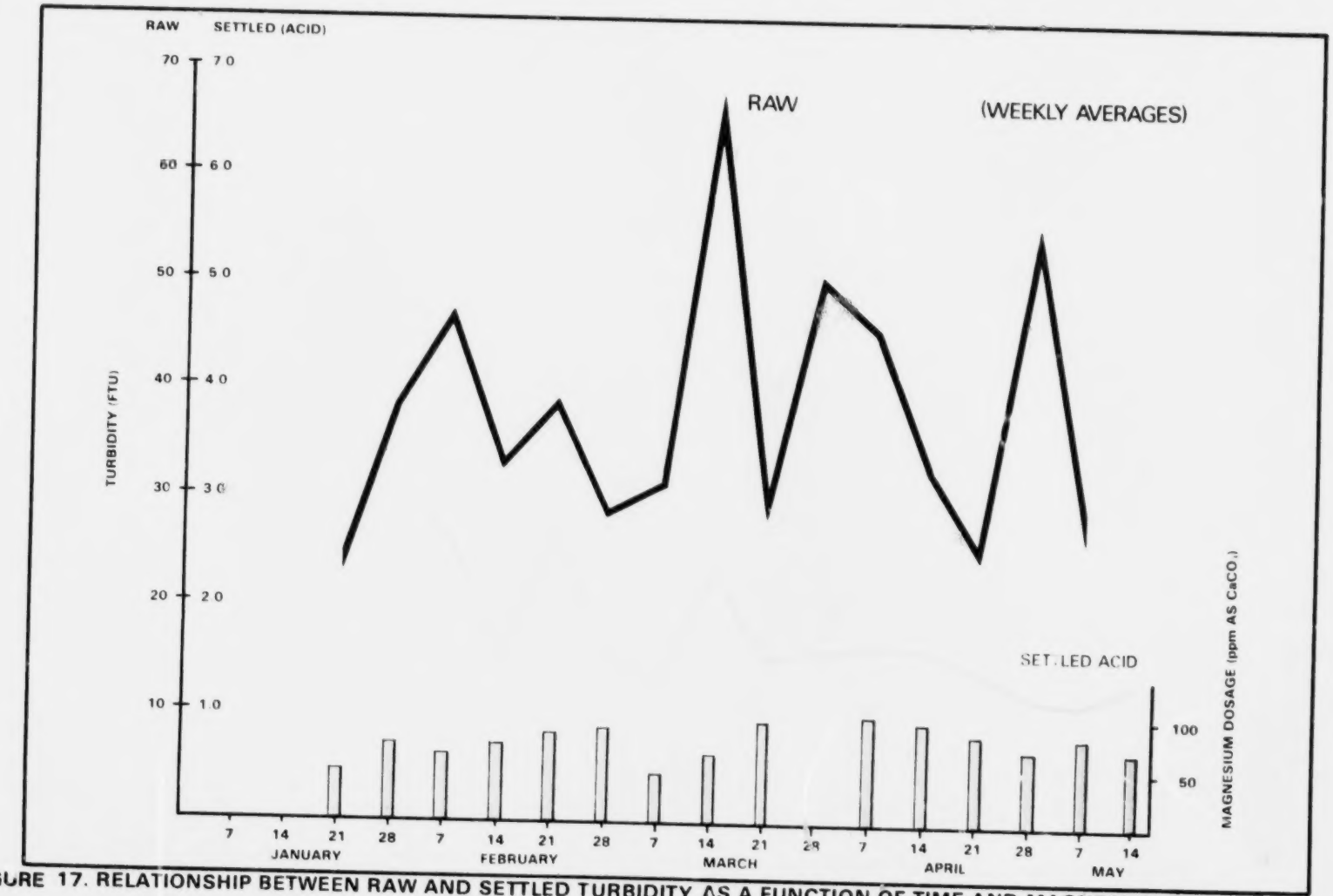


FIGURE 17. RELATIONSHIP BETWEEN RAW AND SETTLED TURBIDITY AS A FUNCTION OF TIME AND MAGNESIUM DOSAGE MONTGOMERY

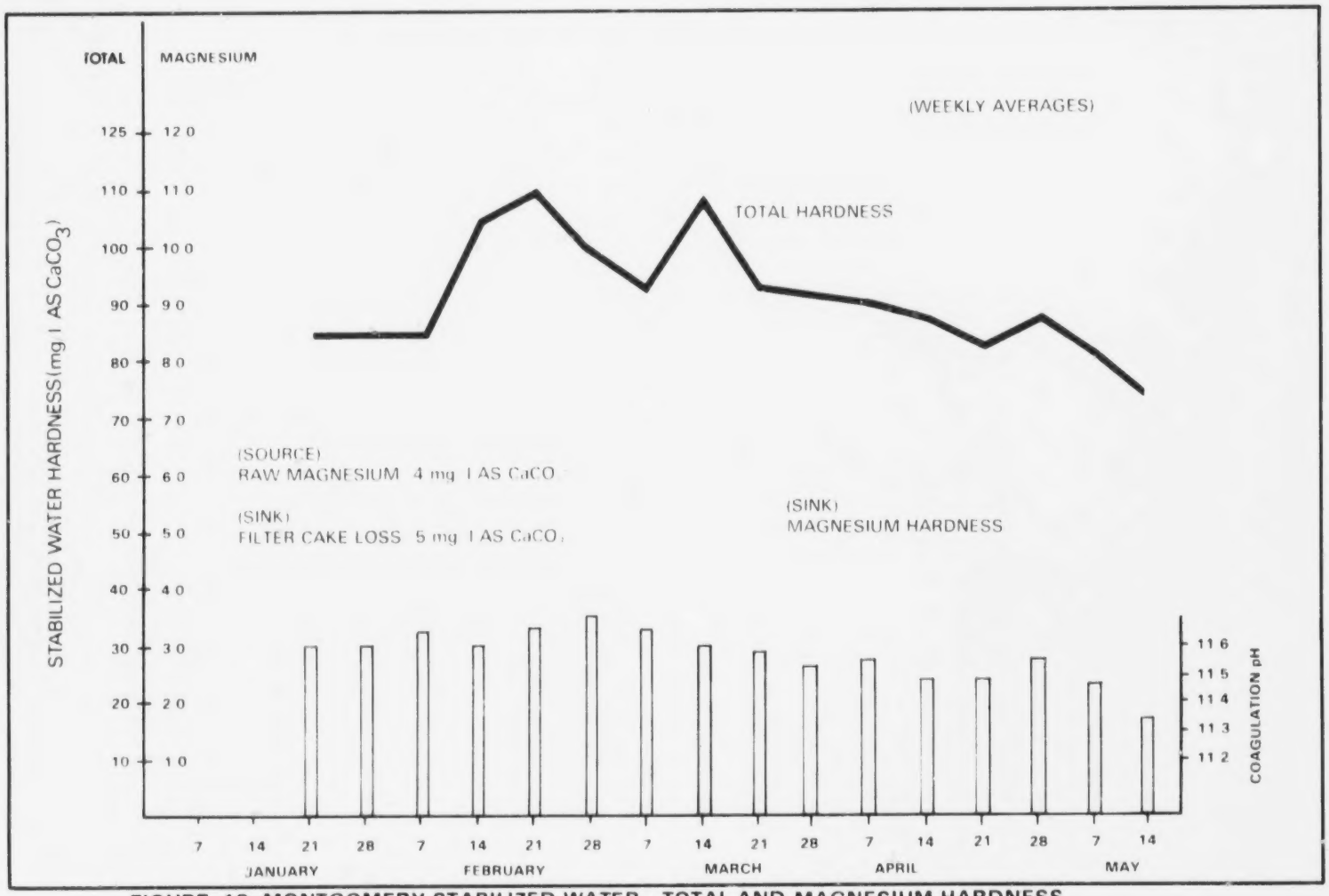


FIGURE 18. MONTGOMERY STABILIZED WATER - TOTAL AND MAGNESIUM HARDNESS

time and coagulation pH. An average total hardness of 82 mg/l as $CaCO_3$ was obtained during the study. A properly designed, two stage stabilization basin will produce a total carbonate hardness of less than 50 mg/l as $CaCO_3$.

OPERATIONAL CHARACTERISTICS

As the degree of magnesium recovery affects the economic feasibility of the process, it is extremely important to account for all losses or gains in magnesium as previously discussed. The coagulation pH to a large extent controls the magnesium loss in the finished water.

Figure 19 illustrates the effect of coagulation pH on magnesium replacement costs for both magnesium sulfate and magnesium carbonate tri-hydrate. An average of 4 mg/l of magnesium as $CaCO_3$ is normally present in the raw water. As a result of the high magnesium content of the cake liquor, thirty pounds per day of magnesium, as $CaCO_3$ in the filter cake, are lost each day. As the coagulation pH increases less magnesium remains in the finished water, therefore, less make-up is required, decreasing the cost per million gallons for magnesium expressed as calcium carbonate.

Figure 20 illustrates the effect of increased coagulation pH on carbon dioxide and lime costs. Chemical costs are based on 50 mg/l of magnesium bicarbonate as calcium carbonate in recycle.

Figure 21 is a summation of Figures 19 and 20 and represents the total cost for magnesium, carbon dioxide, and lime as a function of coagulation pH. An optimum pH of 11.2 was found for the situation where magnesium carbonate tri-hydrate was used as the magnesium source with a total chemical cost of approximately $19.00 per million gallons. Using magnesium sulfate, an optimum pH slightly higher than 11.3

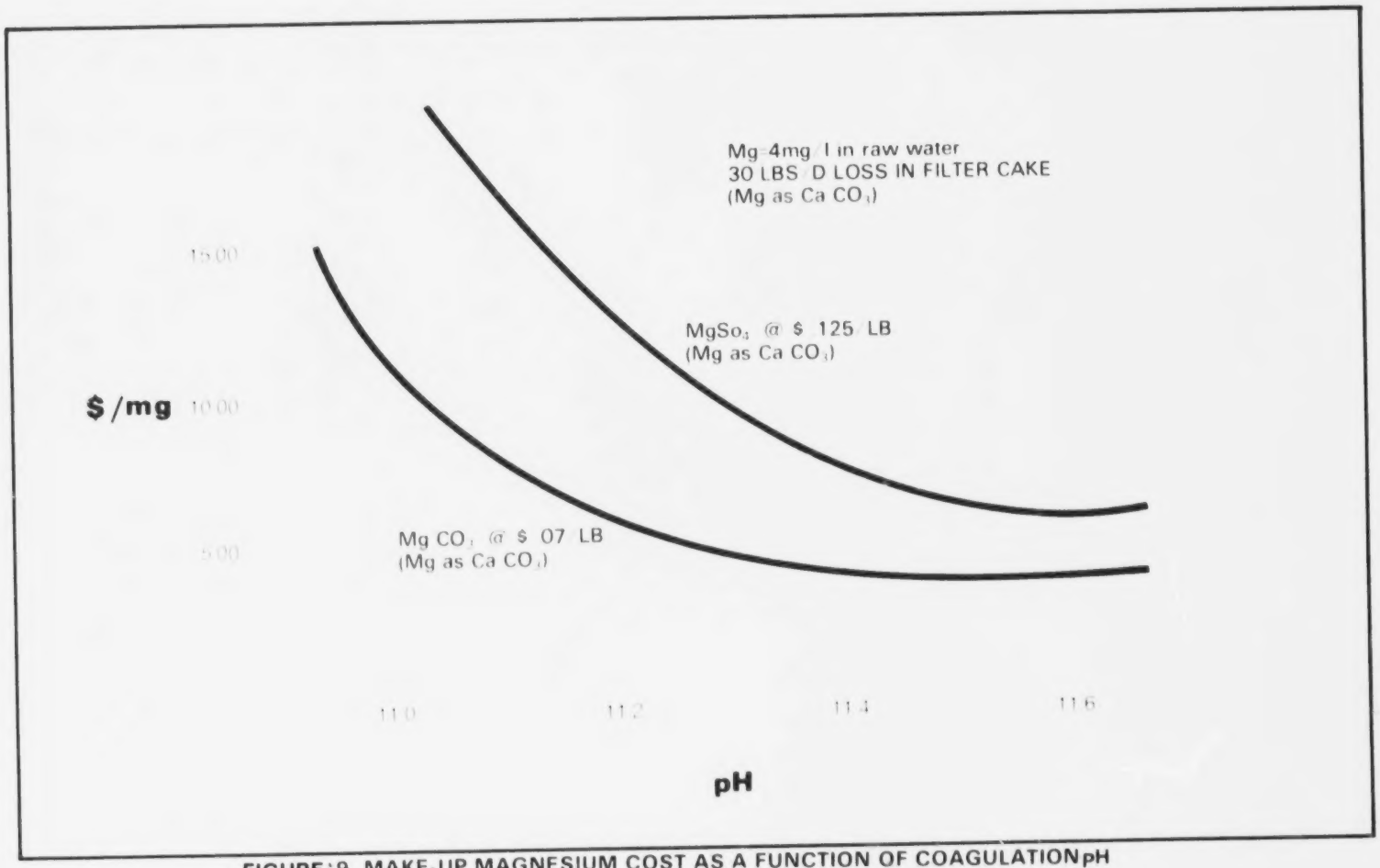


FIGURE 9. MAKE-UP MAGNESIUM COST AS A FUNCTION OF COAGULATION pH
MONTGOMERY

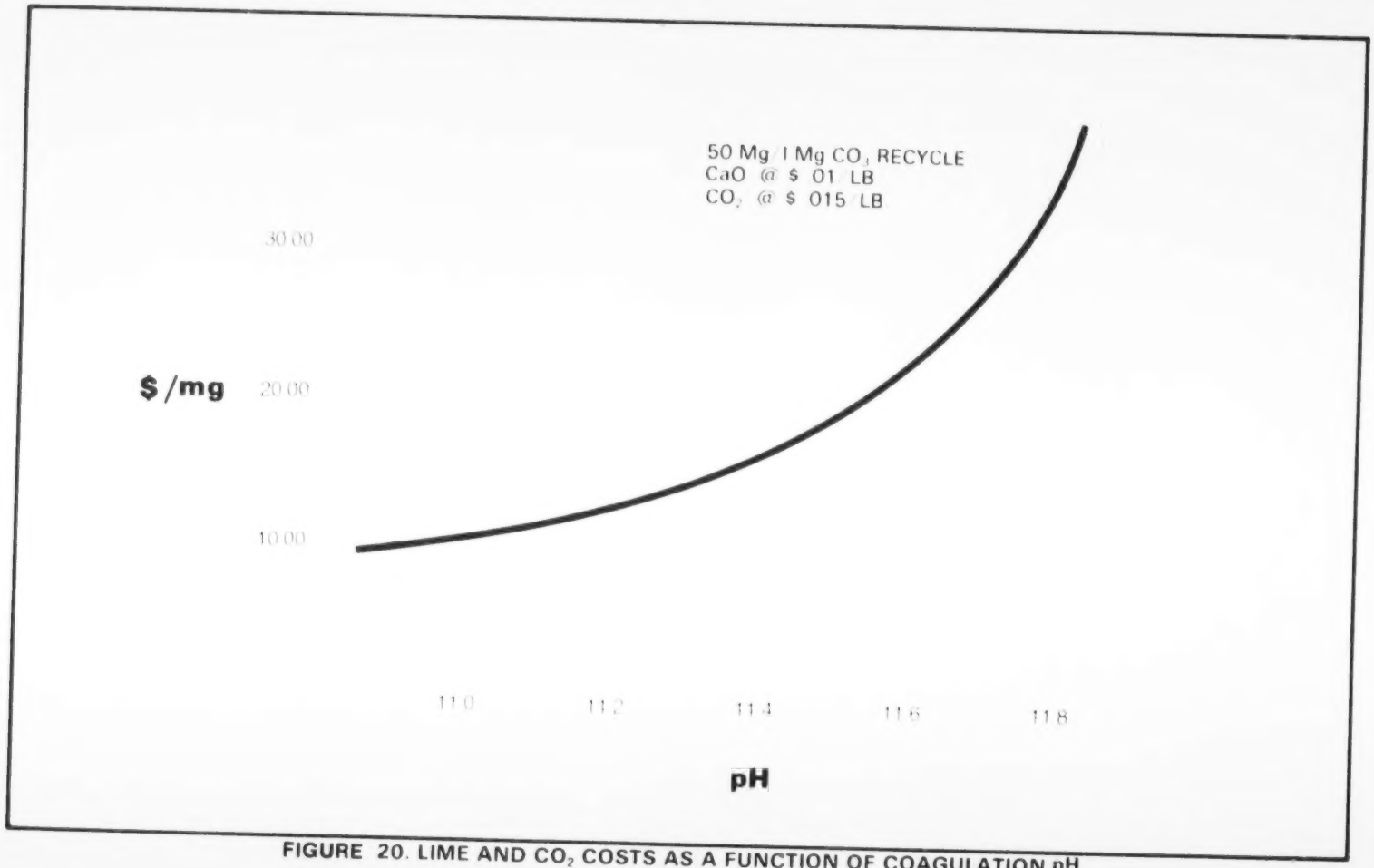


FIGURE 20. LIME AND CO_2 COSTS AS A FUNCTION OF COAGULATION pH
MONTGOMERY

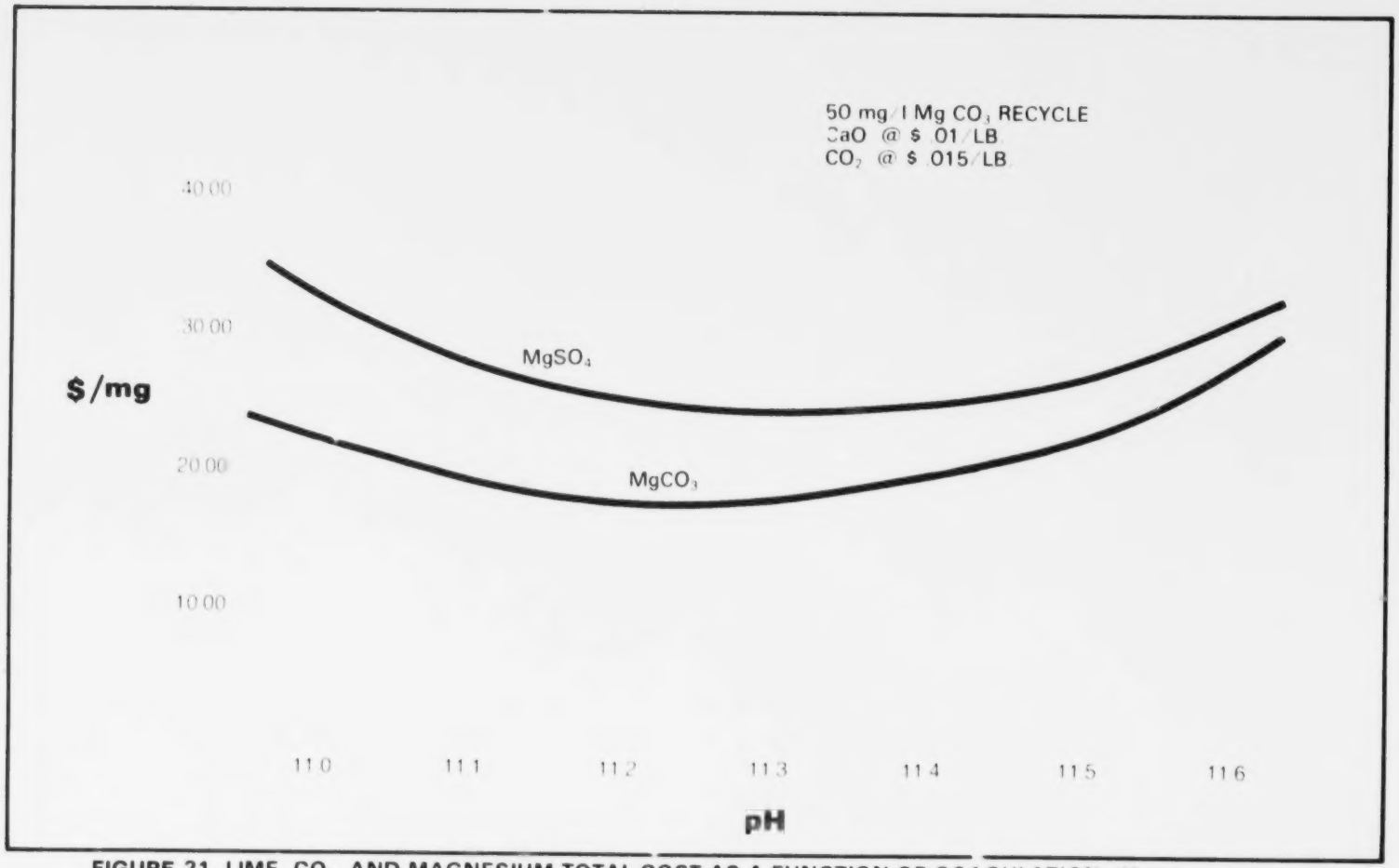


FIGURE 21. LIME, CO_2, AND MAGNESIUM TOTAL COST AS A FUNCTION OF COAGULATION pH MONTGOMERY

is found with a chemical cost slightly higher than $25.00 per million gallons.

If dolomitic lime is used as a source of magnesium, Figure 22 can be used to calculate chemical costs. The only restraint on coagulation pH in this case is to keep the magnesium content in the finished water below some maximum level for hardness consideration; generally requiring the coagulation pH to be kept above 11.0 which would result in a chemical cost of only $10.00 per million gallons.

The results would indicate that the cost estimates published in the earlier papers were conservative. The predicted cost for Montgomery's water of $18.23 was based on a purchase price for carbon dioxide of $20/ton rather than the $30/ton now being paid. Table 17 illustrates the average raw water quality and alum chemical dosages utilized during the study period.

FILTRATION OF STABILIZED WATERS

Filtered water turbidity was recorded on one of the four filters treating alum processed water and three of the four magnesium filters. Filters are normally backwashed after 100 hours of operation or 7 feet of head-loss, whichever comes first.

The months of February and March were selected as representative of normal operation and the records indicated that the alum filter had an average filter run of 82.2 hours and an average head loss of 6.4 feet at the time of washing. During this same time period the magnesium filters averaged 97.8 hours with a head loss of only 3.3 ft. The filter capped with anthracite processing the magnesium treated water averaged over 100 hours filter run with only 1.8 ft. of head loss between washing. When comparing the sand filter processing magnesium treated waters with the

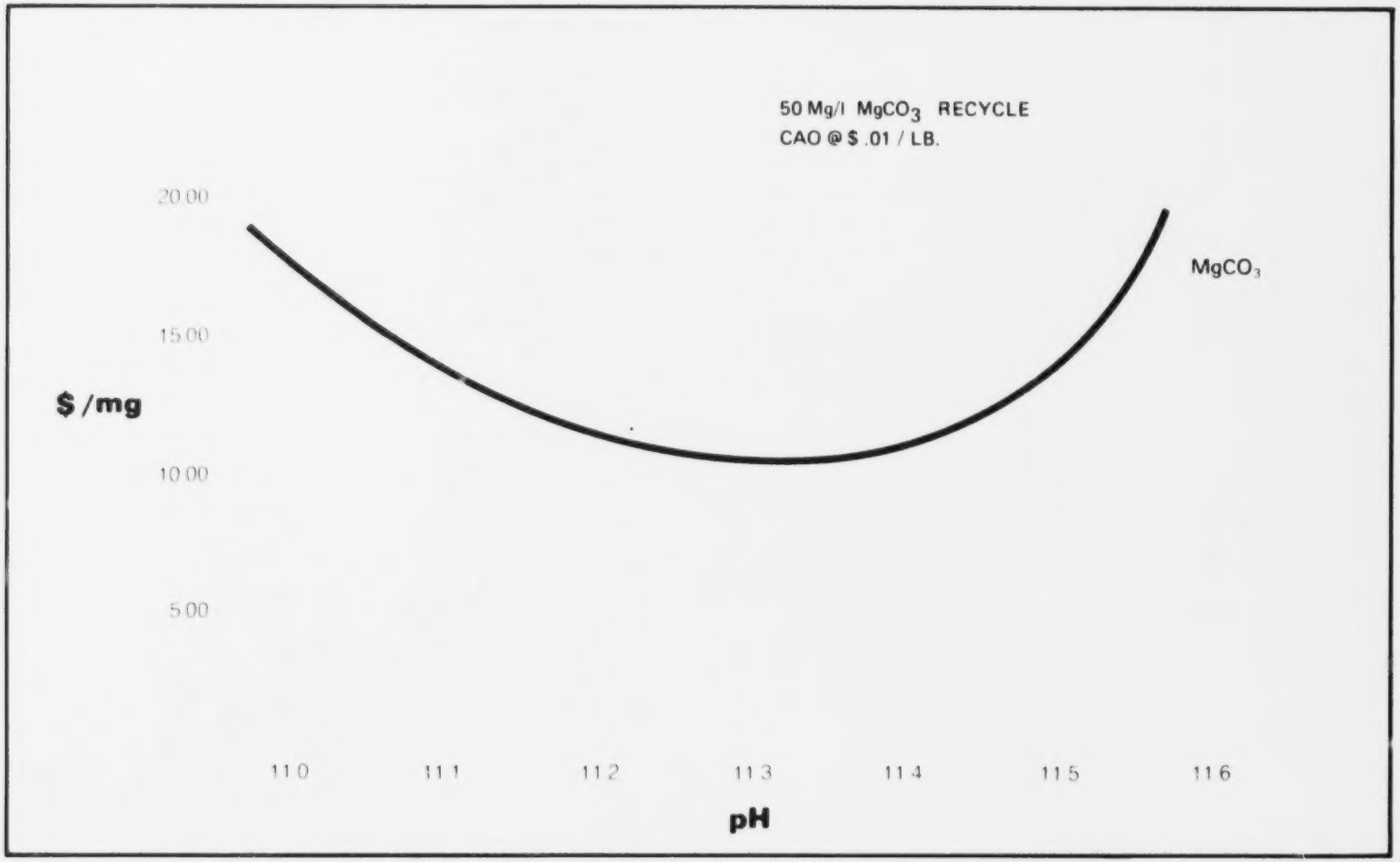


FIGURE 22. LIME AND MAGENSIUM COSTS AS A FUNCTION OF COAGULATION pH MONTGOMERY

TABLE 17. RAW WATER ANALYSES AND ALUM DOSAGES, MONTGOMERY, ALABAMA

Date	Total Alk (As $CaCO_3$)	Total Hardness (As $CaCO_3$)	Turbidity (FTU)	Alum Dosage (mg/l)	Post & Pre-lime Dosage (mg/l)
1/15 - 21	12.1	11.9	23.4	16.5	17.6
1/22 - 28	13.0	12.7	37.7	31.4	18.4
1/29 - 2/4	12.5	12.5	46.5	23.8	18.0
2/5 - 2/11	12.7	13.2	32.8	32.3	27.0
2/12 - 2/18	13.8	15.4	38.5	35.0	21.2
2/19 - 2/25	12.4	12.4	28.5	29.1	17.1
2/26 - 3/4	11.8	11.4	24.7	20.4	13.2
3/5 - 3/11	13.8	15.0	31.1	23.9	15.9
3/12 - 3/18	15.2	20.5	66.4	50.8	21.2
3/19 - 3/25	13.5	15.1	29.1	45.1	22.6
3/26 - 4/1	14.0	15.8	50.5	47.3	14.3
4/2 - 4/8	16.0	13.5	45.7	45.0	19.7
4/9 - 4/15	13.0	13.2	32.5	38.3	19.1
4/16 - 4/22	12.8	14.4	25.3	35.8	17.8
4/23 - 4/29	14.6	13.8	54.3	35.6	19.5
4/30 - 5/6	12.3	14.3	25.1		
AVERAGE	13.3	14.1	37.0	31.2	18.84

anthracite capped filter there is no noticeable difference in filtered water turbidities.

During this time period, an average of 7 FTU (Formizin Turbidity Units) of calcium carbonate turbidity were being placed on the filters. Ideally precipitation will be normal with the better carbon dioxide addition. Based on the experience in Montgomery and the experience of hundreds of softening plants, problems with shortened filter runs are not expected.

Filtered turbidities were generally lower on the magnesium processed water, however, as with the alum process, coagulation efficiency generally determines the filter efficiency.

SOLIDS HANDLING

The design information provided by the laboratory and pilot scaled studies accurately predict full scale performance. The thickener underflow solids ranged from 30% to 45% depending upon the ratio of calcium carbonate to clay in the sludge. Vacuum filter rates ranged from 3 to 20 lbs/sq.ft./hr. Several daily vacuum filter operational data sheets are included as part of the Appendices. Table 18 summarizes the results of the vacuum filter operation.

In freezing weather the vacuum filter could not be operated due to freezing of the vacuum filtrate. The filter rates increased with thickener underflow concentration with an average rate of 4.4 lbs/sq.ft./hr. at 40% solids concentration. Due to the reduced operating time and lower than expected filter rates an average of only 375 lbs/day of dry solids dewatered. The remaining 4,894 lbs was recycled along with the magnesium bicarbonate and stored in the settling basin increasing the percentage of $CaCO_3$ in the sludge. The percentage of magnesium hydroxide in the sludge was initially

TABLE 18. VACUUM FILTER DATA, MONTGOMERY, ALABAMA

Date	Bed Solids (%)	Vacuum Filter Rate ($lb/ft^2/hr$)	Hrs/day	lb/day Dewatered
1/15 - 1/21	29.8	2.28	2.7	166
1/22 - 1/28	25.8	2.69	2.0	145
1/29 - 2/4	20.4	2.17	1.0	59
2/5 - 2/11	22.9	2.25	3.0	182
2/12 - 2/18	32.0	2.72	1.7	125
2/19 - 2/25	41.3	3.69	3.3	330
2/26 - 3/4	48.8	8.77	2.2	521
3/5 - 3/11	39.3	7.42	4.3	861
3/12 - 3/18	38.3	5.69	4.2	645
3/19 - 3/25	34.1	3.34	2.9	261
3/26 - 4/1	36.2	4.94	4.2	560
4/2 - 4/8	37.3	5.36	3.92	567
4/9 - 4/15	40.2	5.28	3.3	470

Carbonator feed sludge went from 4.0% solids to 20.0% solids maintaining the same 17,000 mg/l alkalinity.

42% as $CaCO_3$ reducing to 8.5% near the end of the study. The increase of calcium carbonate and turbidity within the system could be expected to increase the magnesium coagulant requirement.

A series of experiments were performed to evaluate the dewatering characteristics of the carbonated, thickened sludge on sand drying beds. Four beds, 4 ft X 4 ft each with six inches of .5 mm sand on top of three inches of gravel with undrain were constructed. Solids concentrations in excess of 50% were typically found with a drying time of two days to one week required dependent upon climatic conditions. Assuming a one week drying time, it was found that 3 lbs of dry solids

could be dewatered each week per square foot of filter area. The dried cake was easily handled and could be removed readily by front end loader.

CORROSION STUDIES

A Magma Model 8001 Corrosometer was used to compare relative corrosion rates for the alum and magnesium treated waters. Various metal probes are available which change in resistance as corrosion proceeds. The instrument was used to measure this change in resistance each day. A tank was constructed with two compartments open to the atmosphere. Filtered magnesium and alum treated waters were fed during the study with the results illustrated in Figure 23. During this study period, the alum treated waters had an average pH of 8.9 and carbonate hardness of 43 mg/l. The magnesium treated water had a carbonate hardness of 75 mg/l and pH of 8.6. The corrosion rate for the alum treated water was more than double that of the magnesium treated water. Although the pH of the alum treated water was adjusted to a pH in excess of the pH's of calcium carbonate, little corrosion protection was provided due to the low level of calcium and carbonate alkalinity present in Montgomery's water.

COMPARISON WITH ALUM PROCESS

Table 19 summarizes the comparison between the alum and magnesium for treatment of the Montgomery water.

PROCESS ECONOMICS AND ENERGY CONSIDERATIONS

Economics

Considering process economics, one must include chemical costs, capital costs, operating and maintenance costs,

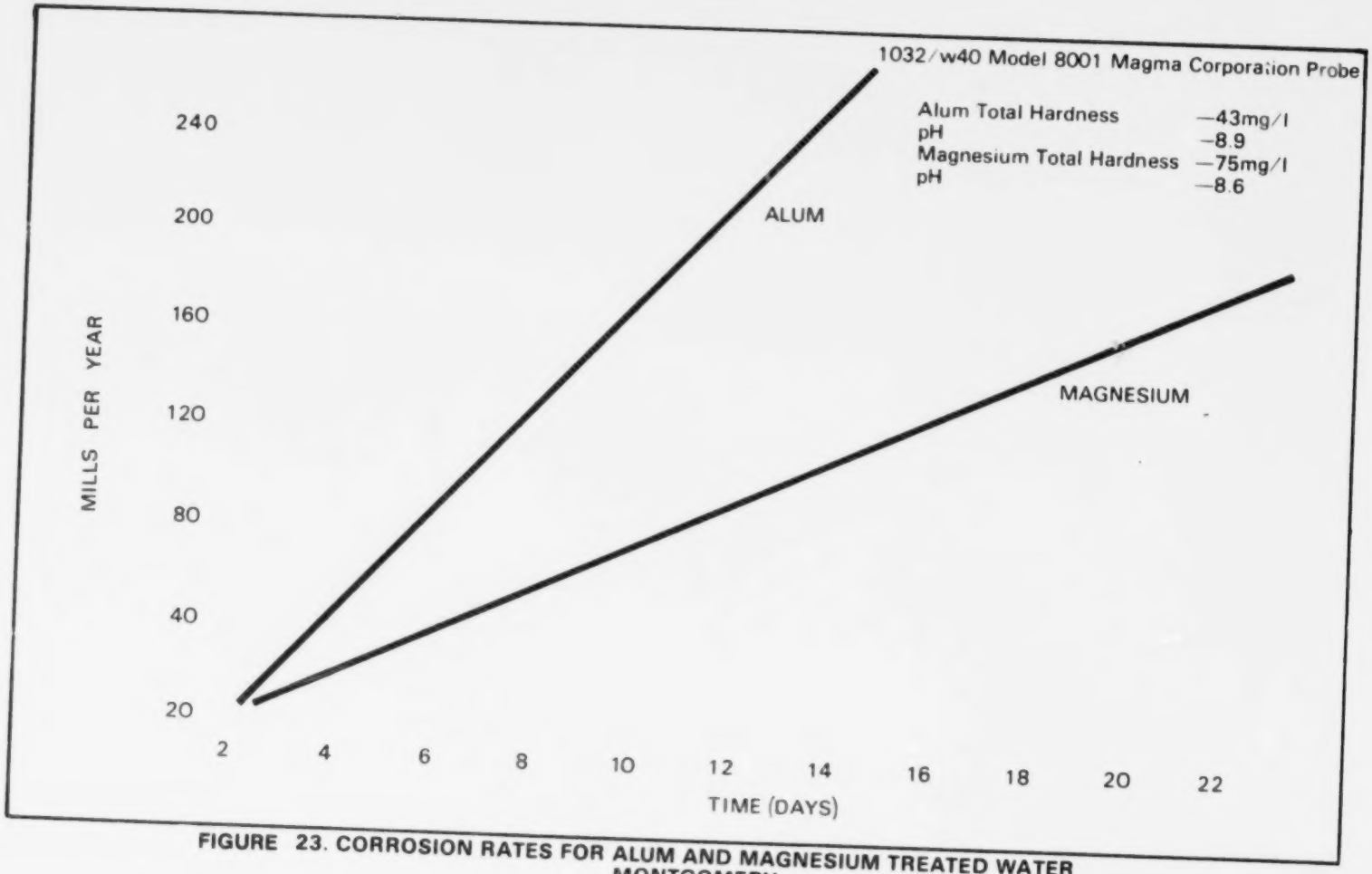


FIGURE 23. CORROSION RATES FOR ALUM AND MAGNESIUM TREATED WATER MONTGOMERY

TABLE 19. COMPARISON OF THE MAGNESIUM AND ALUM TREATMENT PROCESSES AT MONTGOMERY

Parameter	Magnesium	Alum
Chemical Dosages & Coagulation pH	875 #/M.G. CaO, 800 #/M.G. CO_2, and 100 #/M.G. of $MgSO_4$, pH 11.2, highly buffered	250 #/M.G. of alum, 208 #/M.G. of $Ca(OH)_2$, pH from 6.0 - 6.4 poorly buffered.
Floc Characteristics	Precipitation products, dense, granular Form rapidly, and not as kinetically dependent upon water temperature.	Hydrolysis products, flocculant much larger in size, form slowly with gentle mixing much slower at colder temperatures.
Settling Characteristics	Rapid, increased clarifier loading rates, between lower rate for alum and high rate for softening plant. High pH disinfects.	Generally less than .75 gal/sq. ft./min. loading rate, sensitive to velocity gradients in settling basin
Sludge Characteristics	Carbonated sludge thickens to 40% to 50% solids. Approximately 1000 #/M.G. produced but all solids are dewatered as an integral part of the process. All sludge water recovered.	Gelatinous sludge normally less 1% solids which can be thickened only to about 6% solids, approximatley 400 #/M.G.
Filtration Characteristics	Generally lower filtered water turbidity calcium carbonate loading will not shorten filter runs.	Filter runs dependent upon amount of floc carryover.
Finished Water Characteristics	Slightly increased hardness and alkalinity; 40 - 50 mg/l as $CaCO_3$, allows pH adjustment for corrosion control.	Very low alkalinity and hardness, generally more red water, corrosion problems.

TABLE 19. COMPARISON OF THE MAGNESIUM AND ALUM TREATMENT PROCESSES AT MONTGOMERY

Parameters	Magnesium	Alum
Chemical & Operations Economics	Less favorable for low alkalinity waters increased chemical cost unless CO_2 source becomes available or domonitic lime proces successful.	Lower Chemical cost and less operating and maintenance expense when alum sludge is not treated for disposal.

[1] Dependent upon water conditions

[2] Assuming more efficient first stage carbonation

as well as the various treatment considerations which includes sludge treatment in many cases.

Based on the previous discussions, a chemical cost of $13/million gallons is a reasonable estimate for the Magnesium Process. During the project period, an average alum dosage of 31.2 mg/l and lime dosage of 18.8 mg/l resulted in a chemical cost of $7.96/million gallons.

In order to convert the Montgomery plant to the magnesium process it is estimated that a capital cost of $300,000 would be required. These costs are summarized in Table 20. Amortizing over thirty years at 6% interest would result in an annual cost of $21,586 or $2.96/million gallons of water treated (assuming 20 MGD production). Based on the operating experience during the study period, no additional labor cost would be expected.

The calcium carbonate-turbidity sludge produced serves as an excellent soil stabilizer. At one plant in south Florida, calcium carbonate sludges are sold to cattle farmers for $1.50/ton, picked up at the plant site by the purchaser. Considerable calcium carbonate is sold for this purpose in Alabama. For this reason, it can be safely assumed that the dewatered sludge can be cleaned from the sand drying beds and disposed of at little or no cost in the immediate area surrounding the water plant.

The additional costs for the application of the magnesium process at Montgomery can be summarized as:

Additional Chemical Cost	$/MG	$/yr
$13.00-$7.90	$5.10	$37,230
Capital Cost		
$300,000 @ 6% for 30 yrs.	$2.96	$21,586

TABLE 20. ESTIMATION OF CAPITAL COST FOR MONTGOMERY'S PLANT CONVERSION

	Cost ($)
Stabilization of Settled Water	
20 minutes contact chamber	50,000
Instrumentation & Controls	15,000
Mixing Equipment	10,000
Sludge Thickening	
20' diameter thickener	50,000
Yard piping, sludge pumping, & control	30,000
Sludge Carbonation	
Carbonation cells	25,000
Instrumentation & Control	10,000
Recycle of Magnesium Bicarbonate	
Recycle storage tanks, pump & control	20,000
Sludge Drying Beds	
20,000 sq. ft. @ $2.50/sq.ft.	50,000
Filtrate recycle & piping	15,000
	$275,000
Engineering	25,000
TOTAL	$300,000

Maintenance

2% of Capital Cost	$0.82	$ 5,986
Electrical Cost		
60 HP @ $0.01/KWH	$0.055	$ 405
	$8.94	$65,207

OR

$65,207 per year

Allocating these costs to the dry solids produced with the alum process would represent a cost of $34.00/ton for dewatering and disposal. This is significantly lower than would be expected with alternative sludge treatment processes.

Energy Considerations

Approximately 1500 Hp are required to treat and distribute 20 MGD of water in Montgomery. The additional horsepower requirements, 60 Hp, will only add approximately 4% to the existing plant power requirements.

MELBOURNE FULL SCALE RESULTS

As was the case in Montgomery, the magnesium process has been found to compare favorably with the presently used alum process in both overall operation and water quality produced. Figure 24 illustrates the relationship between raw water color and treated water color as a function of

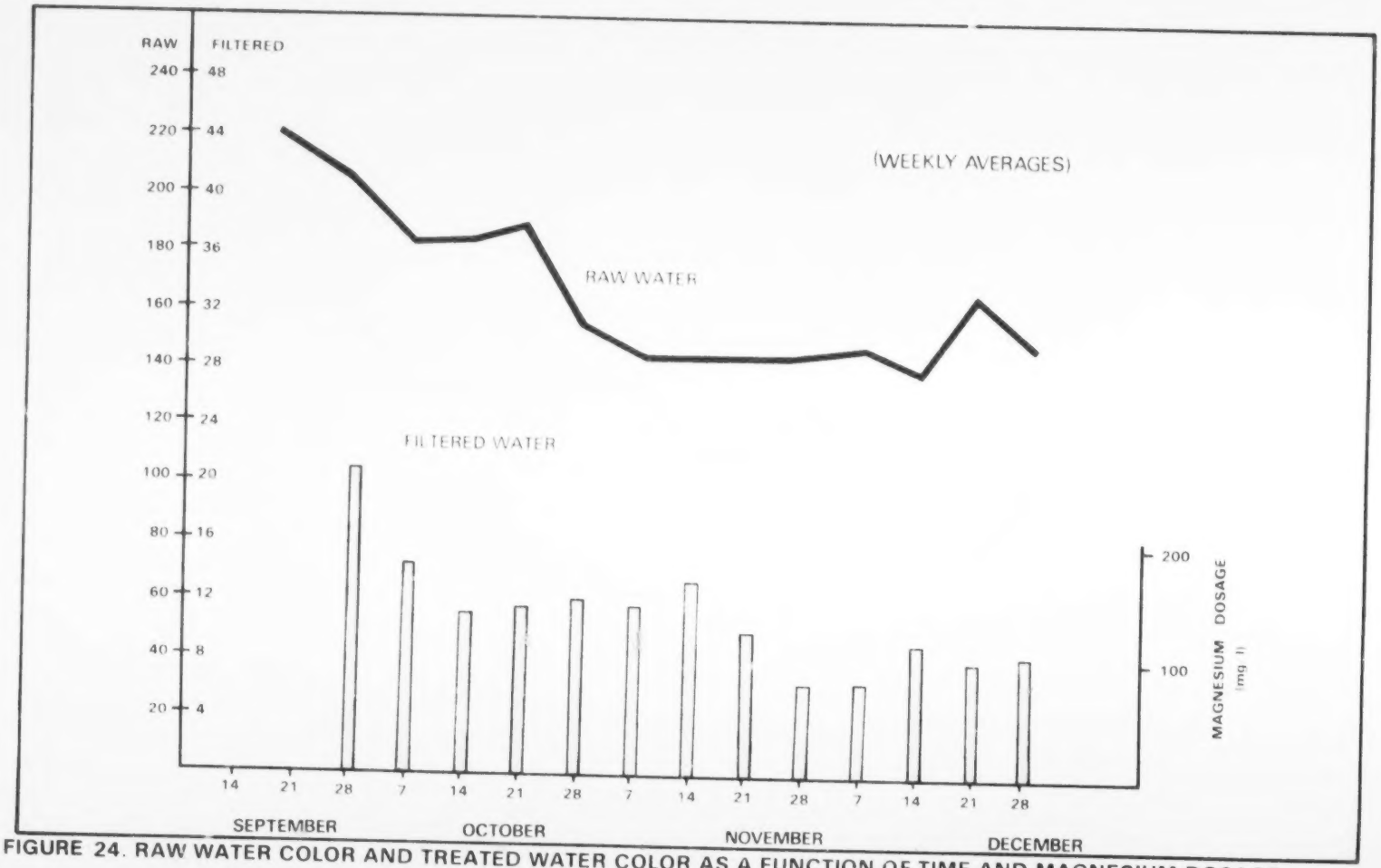


FIGURE 24. RAW WATER COLOR AND TREATED WATER COLOR AS A FUNCTION OF TIME AND MAGNESIUM DOSAGE

time and magnesium dosage. It has been found that the most economical treatment at Melbourne occurs when the color levels are reduced by coagulation to 15 - 20 Pt.-Co. units and chlorine was used to bleach the final color to less than 5 units. It is interesting to note that the treatment efficiency improved after several months of operation even at lower chemical dosages, obviously the result of increased operator proficiency. The organic color level in the raw water did not decrease in the late Fall as would have been predicted from past experience.

As discussed previously, the degree of magnesium recovery somewhat determines the economic feasibility of the process. It is extremely important to account for all losses or gains of magnesium. The losses of magnesium occur in two areas - the magnesium content in the finished water and the magnesium lost in the moisture of the filter cake produced. Sources of magnesium include magnesium present in the raw water as well as any magnesium source fed in the process. Figure 25 illustrates the magnesium balance for Melbourne. The high moisture content in the filter cake resulted in the equivalent loss of 12 mg/l of magnesium as calcium carbonate in the raw water. The finished water produced contained an average of 6 mg/l. An average of 11.5 mg/l of magnesium was found in Melbourne's raw water during the study period. It is probable with proper filter cake washing the magnesium loss in the dewatered sludge can be reduced.

During the course of the study a large amount of data has been collected. Routine data sheets are included as Item 3 in the Appendix and show the type and quantity of data collected each day by the water plant operators. In addition, a summary of daily average results are included.

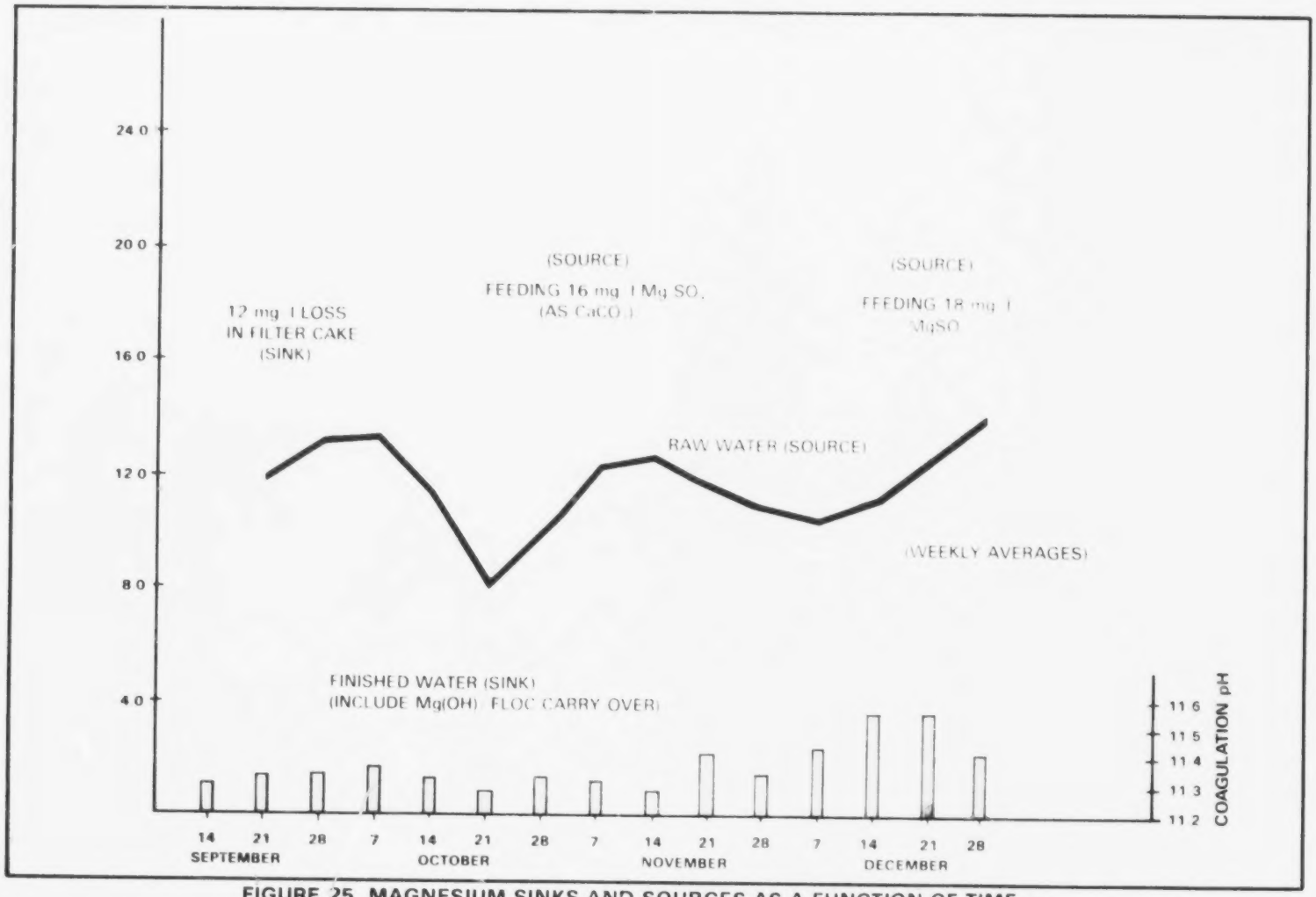


FIGURE 25. MAGNESIUM SINKS AND SOURCES AS A FUNCTION OF TIME – MELBOURNE

Study of "Color Balance"

One of the most important findings of the Melbourne study is shown in Figure 26. If color release on sludge carbonation was to prove a problem, the ratio of organic color to magnesium concentration in the recycled liquor should have increased with the time that the system is in operation. This was not the case, however, as the ratio tended to decrease. This was probably due in part to the feed of make-up magnesium sulfate as indicated on the graph.

Chlorine Demand Studies

A series of chlorine demand studies were performed at the Melbourne water plant. These studies were conducted to determine the effect of free chlorine residual on color reduction as well as to determine the chlorine demand for both the alum and magnesium treated waters. Table 21 illustrates typical results from one of these tests.

Studies of Carbonated Sludge Dewatering and Thickening

Sludge dewatering studies were conducted on the carbonated sludge thickener underflow the week of October 1. Results of leaf filter testing are shown as Table 22. Results of full scale vacuum filter operation are shown as Table 23. A full scale thickening study was made during the period December 20 through January 6. The results are shown in Table 24. Excellent agreement between leaf filter and full scale operation was found, as was the case in Montgomery.

Taste and Odor Studies

Considerable effort was expended in evaluating the

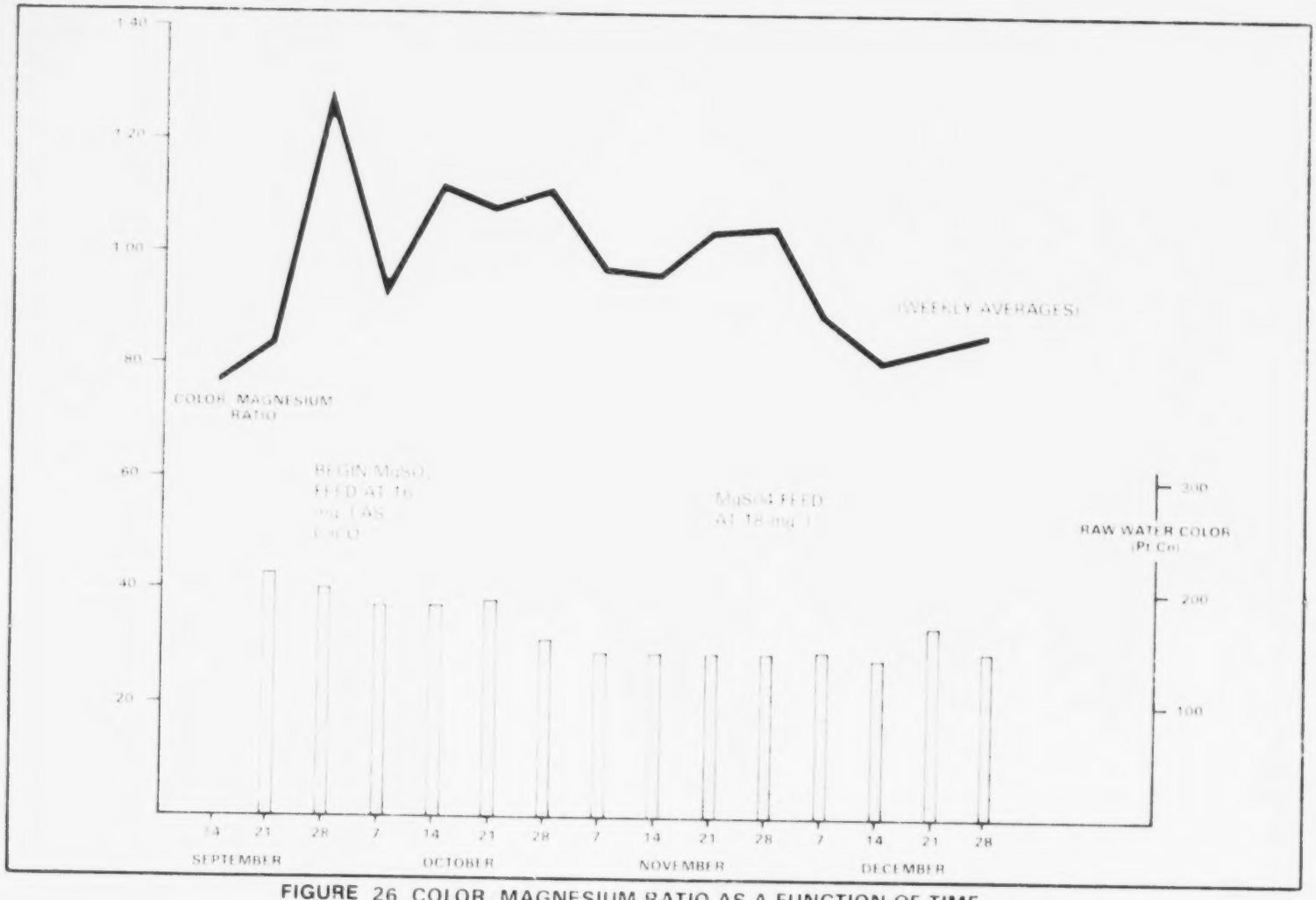


FIGURE 26 COLOR MAGNESIUM RATIO AS A FUNCTION OF TIME — MELBOURNE

TABLE 21. CHLORINE DEMAND TEST

(10-5-73)

Magnesium Treated Water

Free Chlorine at Indicated Time (Minutes)	ppm of Chlorine Added					
	2	3	4	5	6	7
15	0.15	0.25	1.00	1.50	1.50	1.50
30	0.15	0.15	0.35	0.75	1.50	1.50
60	0.15	0.15	0.35	0.50	0.50	1.00
120	0.10	0.15	0.15	0.25	0.25	0.45

Initial color 25; Final color 7 at 7 ppm Chlorine dosage

Alum Treated Water

Free Chlorine at Indicated Time (Minutes)	ppm of Chlorine Added					
	2	3	4	5	6	7
15	0.15	0.35	0.50	1.00	2.50	2.50
30	0.15	0.15	0.30	1.00	2.00	2.00
60	0.10	0.15	0.15	0.40	0.50	1.00
120	0.10	0.15	0.15	0.15	0.20	0.50

Initial color 10; Final color 5 at 7 ppm Chlorine dosage

TABLE 22. LEAF FILTER TEST RESULTS - MELBOURNE

Form Time (sec)	Dry Time (sec)	Bed (% solids)	Filter Rate ($lb/ft^2/hr$)	Cake Moisture (%)
30	60	41.8	43	45
60	90	41.6	38	45
90	120	41.7	30	46
120	180	41.7	26	44
30	60	15.0	17	44
60	90	14.7	14	46
90	120	13.1	11	45
120	180	12.6	9	45

TABLE 23. FULL SCALE VACUUM FILTER RESULTS - MELBOURNE

Form Time (sec)	Dry Time (sec)	Bed (% solids)	Filter Rate ($lb/ft^2/hr$)	Cake Moisture (%)
171	338	41.9	20.0	45
234	278	41.9	17.6	45
260	251	41.9	19.7	45
342	170	41.9	19.7	45
171	338	28.9	12.6	43
234	278	28.9	11.7	44
260	251	28.9	12.4	45
342	170	28.9	13.5	46

TABLE 24. MELBOURNE SLUDGE THICKENING STUDY

Date	Thickener Feed			Thickener Underflow			
	GPM	% Solids	lb/day	GPM	% Solids	lb/day	lb/ft^2 /day
2/20	5.0	9.33	5987	1	29.22	4205	53.9
2/21	5.0	10.55	6580	1	30.20	3929	50.0
2/22	7.5	9.19	8599	1	27.30	3900	49.0
2/23	7.5	10.29	9905	1	21.58	3028	38.6
2/24	10.0	9.38	12,039	1	24.56	3535	45.03
2/24	10.0	9.18	11,779	1	24.67	3492	44.49
2/25	10.0	10.14	13,014	1	25.15	3620	46.12
2/26	5.0	9.39	6019	1.5	25.85	5582	71.1
2/27	5.0	10.35	6645	1.5	25.48	5502	70.1
2/28	7.5	10.34	9953	1.5	25.50	5505	70.1
2/29	7.5	8.82	8490	1.5	24.90	5376	68.5
2/30	10	9.98	12,578	1.5	25.76	5561	70.8
2/31	10	7.96	10,216	1.5	24.20	5224	66.6
3/1	5	8.55	5486	2.0	20.47	5696	72.58
3/2	5	10.04	4671	2.0	20.28	5643	71.8
3/3	7.5	8.86	8529	2.0	19.07	5306	67.0
3/4	7.5	9.70	9337	2.0	20.04	5624	71.6
3/5	10.0	11.09	14,238	2.0	20.13	5601	71.4
3/6	10.0	7.50	9626	2.0	18.78	5226	66.6

use of potassium permanganate for taste and odor removal. It was found that at the high coagulation pH of 11.3 extremely rapid reactions occurred between the potassium permanganate and the organics present in the water. As the permanganate would not selectively oxidize the compounds producing odor and taste, very large dosages were required to effectively remove taste and odor. The potassium permanganate could be fed at the raw water intake for reaction with the taste and odor components prior to reaching the plant and subsequent pH elevation in rapid mixing. However, as low carbon dosages were adequately preventing taste and odor problems, no action was taken to further investigate the use of potassium permanganate.

The elevated pH had little effect on carbon adsorption of taste and odor. Essentially the same carbon dosages were used to maintain similar quality treated waters on both the alum and magnesium treated processes.

Studies of "Organics" Present in the Raw Water

Samples of raw water, finished water treated with alum and with magnesium carbonate were collected over a twenty-four hour period, separately composited and shipped by Air Express to the Athens, Georgia laboratory of the Environmental Protection Agency for analysis by gas chromatography. In addition, organics in each of the three waters were continuously removed over a two day period in special filters provided by the E.P.A. Cincinnati laboratory and shipped to that laboratory for analysis.

Two sets of samples were analyzed for total organic carbon. The raw water was found to have 37 mg/l on September 12 and 28 mg/l on October 9. The alum treated water ranged in TOC from 10 mg/l on October 9 to 18 mg/l on September 12.

One sample taken October 9 found the magnesium treated water to have 12 mg/l of TOC.

The results of the studies related to determining and quantifying the organics present in Melbourne's raw and treated waters were somewhat indefinite. E.P.A. has developed a procedure for extracting the organic carbon onto carbon columns in a specified manner. These carbon filters were than mailed to E.P.A. for extraction of the organics from the carbon with both alcohol and chloroform. The alcohol extract is called CAE; the chloroform extract is called CCE. The CCE value for the raw water ranged from 1.1 to 1.7. The magnesium treated water ranged from 1.0 to 1.6 and the alum treated water ranged from 2.4 to 2.5. The CAE values for the raw water were 3.9, with magnesium treated water 4.2 and alum treated water 11.3. All of these values are extremely high. It is interesting to note that neither the alum nor the magnesium process removed these organics, although color removal was taking place. This is also upheld in the TOC analysis reported earlier. While the color was essentially completely removed, only 50% of the TOC was removed as a result of the treatment process.

The increase in carbon as a result of the alum process could possibly be explained by the fact that during periods when the filter head loss is high alum floc is actually pulled through the filter which contained high concentrations of organic material absorbed on the floc. These results would indicate that neither process is effective in completely removing the organics adsorbed on these columns.

E.P.A. has completed extensive analysis for heavy metals in both the alum and the magnesium treated waters. The magnesium treated water showed metals concentrations of 50% or less, of those found in the alum treated water. There were no significant concentrations of metals found in

either, however. As an example, copper was 17 parts per billion in the alum treated water and 9 parts per billion in the magnesium treated water. Zinc was 190 parts per billion in the alum treated water and 76 parts per billion in the magnesium treated water. These results are included in the Appendices as Appendix D, together with correspondence with the E.P.A. laboratories concerning the organics studies.

Pilot Calcination Results

Near the end of the study, several drums of dewatered, but unwashed, sludge were shipped to the BSP Division of Envirotech in Brisbane, California for a continuous calcination study in a 30" diameter multiple hearth furnace. The results of this study, as indicated below, were somewhat inconclusive.

The most important aspect of this study was the relatively poor quality lime produced. Only quick-lime containing 63.2% calcium oxide content was produced. This can be explained for the following reasons:

1) The nature of the multiple hearth furnace is such that temperatures in excess of 1750°F are damaging to the mechanical components. In the calcining zone of a rotary kiln temperatures in excess of 2000°F are usually employed. Due to the geometry of the pilot furnace, severe short circuiting between hearths was evident. The increased temperatures would probably have increased the calcium carbonate conversion efficiency and produced a more reactive product.

2) More important, however, relatively poor lime was used initially in the project. So poor that one

shipment was rejected. This lime has approximately 15% inerts and would result in build-up of the inert fraction of the sludge tested. In full scale operation, it would be extremely important to begin with the highest quality lime possible.

3) The sludge studied was the result of many hundreds of cycles of coagulant reuse. It is possible that some build-up of inerts from the raw water is possible after this period of operations. Periodic wasting of lime may be required. However, this will not be more frequent than the six month period of this study. The wasted lime would have considerable value as a soil pH conditioner.

Lime recalcination at Melbourne would appear both economically and technically feasible. Considerable attention should be directed to determining which type of hearth furnace should be used: rotary kiln, multiple hearth furnace or fluo-solids reactor. Each offers advantageous features and a thorough evaluation is required.

Design Table Summary

Table 25 summarizes the design criteria determined from both the Montgomery and Melbourne studies.

In the design of the sludge carbonation device, using furnace exhaust gas as a carbon dioxide source may result in a foaming problem. The 80% air content in the exhaust gas may cause foam due to the surface properties of the organic color in the recovered magnesium bicarbonate liquor. This foam can be collected and drained to the tail

TABLE 25. DESIGN TABLE SUMMARY

Unit	Design Parameters	Comments
Rapid Mix	10 - 30 seconds	Short rapid mix appears to be desirable in color removal applications.
Flocculation	15 - 30 minutes	Floc forms rapidly. However, contact time increases color adsorption.
Clarifier	1.0 gal/sq.ft./min.	The use of polymers prevents excessive $Mg(OH)_2$ floc carry-over.
Filtration	2.0 - 4.0 gal./sq.ft./min.	Filter rates up to 4.0 gal/sq.ft./min. were evaluated in Montgomery. Increased rates improved performance normally.
Settled Water Carbonation	10 - 30 minutes	Two stage, separated by time, shown as design parameters.
Sludge Carbonation		
Purchased 100% CO_2	15 minutes	
Kiln Gas 18% CO_2	60 minutes	Foaming problems solved by collection in launder drained to tail box.
Sludge Thickening	40 - 50 lbs/sq.ft./day	Increase in loading rate will produce solids underflow less than 30%.
Sludge Dewatering	25 - 35 lbs/sq.ft/day	Lower rate is for feed solids less than 30%.

box with a launder on one side of the unit.

Miscellaneous Studies

Calcium carbonate precipitation within the filter media was not found to be a problem as long as the pH of the stabilized water was kept below 8.6 to 8.8. The anthracite filter seemed to be less affected by calcium carbonate precipitation.

The length of filter operation between backwashing affects the net water produced. For the period October 1 through November 15, the alum process sand filter averaged 37.3 hours between backwashing and the anthracite-capped (3") filter averaged 40.5 hours. During the same time period, the magnesium process sand filter averaged 37.0 hours and the anthracite-capped filter averaged 45.5 hours between washings. Later in the Fall it was reported that the alum filters were being washed considerably more frequently due to "air binding" while the magnesium filters maintained the same total hours of operation. The granular calcium carbonate turbidity produced in the stabilization of the clarified magnesium treated water, while considerable in quantity, does not have the filter-binding properties of alum floc carryover.

During the course of the study an excess of both lime and CO_2 was used. Near 100% transfer efficiency is possible with pure CO_2 in a properly designed carbonation basin. Due to the short retention time and shallow water depth in the effluent clarifier launders, efficiencies of 50% or less were achieved.

Lime feed was not maintained to provide a uniform coagulation pH. A reduction of approximately 20% in lime requirements would be predicted from the data sheets for an

average CaO feed of 275 mg/l. This can be accomplished primarily through the use of properly designed lime handling and feeding equipment as well as automatic pH control.

ECONOMICS AND ENERGY CONSIDERATIONS

Economics

The chemical costs will be evaluated both with and without lime recalcination and the purchase of lime and carbon dioxide.

Looking first at the costs associated with lime recalcination and the purchase of lime and carbon dioxide, the recovery of 15 tons/day of lime can be estimated as:

Capital Costs	$/year	$/ton of CaO
$900,000 for 25 years @ 6% (25 ton/day kiln)	69,595	12.71
Maintenance		
2% of Capital Cost	18,000	3.30
Power (Gas & Electricity)		
$11.00 per ton CaO	60,225	11.00
Operation		
Four (4) operators @ $8,000/yr	32,000	
1/2 Maintenance @ $8,000/yr	4,000	
1/4 Management @ $10,000/yr	2,500	
	38,500	7.03
TOTAL (Based on an average production of 15 tons/day)	$186,320	$34.04

When producing 10 tons per day, as in the Winter period, the costs will climb to $45.54 per ton. As lime requirements increase due to increases in water production, the cost per ton will decrease. Producing 25 tons per day of CaO will result in a cost of $24.82 per ton of lime.

In calculating the chemical costs for water treatment, the following costs are assumed:

Lime - Delivered at $30/ton CaO

CO_2 - Delivered at $30/ton CaO

Lime - Calcined at $39.79/ton CaO
(Average production at 12.5 tons/day)

Magnesium Sulfate - at $240/ton magnesium as Calcium carbonate (magnesium carbonate should be available at $100/ton within 12 months)

The average chemical dosages on an annual basis are:

CaO	-	225 mg/l
CO_2	-	155 mg/l
Magnesium	-	5 mg/l

With lime recovery, the cost per million gallons would be:

CaO -	225 X 8.33 X $0.019 =	37.29
CO_2 -		- 0 -
Magnesium	5 X 8.33 X $0.12 =	5.00
TOTAL		$42.29

The cost not recovering lime would be:

CaO -	225 X 8.33 X $0.015 =	28.11
CO_2 -	155 X 8.33 X $0.015 =	19.37
Magnesium	5 X 8.33 X $0.12 =	5.00
TOTAL		$52.48

It is interesting to note that chemical costs, with recalcination, are only slightly affected by increases in chemical dosages. This would allow the operation a large safety factor in treatment at a very modest cost.

On an annual cost basis, the cost for coagulation and stabilization chemicals would be:

With recalcination	-	$154,358
Purchase Lime + CO_2	-	$191,552
Alum and Lime	-	$94,170

This is based on an average water production of 10 MGD.

The capital costs required to modify both the North and South Melbourne plants to use the magnesium process have been estimated to be $612,900.[15] This cost is only for the additional units required to include the magnesium process and is included for comparable purposes only. The cost does not include plant modification required to increase the capacity to 22 MGD. Amortized over twenty-five years at 6% interest would require $47,394 per year for capital recovery. Maintenance at 2% of capital cost would amount to $12,258 per year. Operation would not require any additional personnel with recalcination, as the furnace operators would also be responsible for sludge dewatering. Without recalcination, a cost of $16,000 has been estimated for operation of the vacuum filter and sludge thickening.

To summarize the total costs for water treatment utilizing the magnesium process:

Lime Recalcination	$/year
Chemical Costs	154,358
Capital Amortization	47,394
Maintenance	12,258
Electrical Power	3,000
TOTAL COST	$217,010

Purchase Lime and CO_2	
Chemical Costs	191,552
Capital Amortization	47,394
Maintenance	12,258
Operation	16,000
Electrical	3,000
TOTAL COST	$270,204

Lime recalcination will produce some excess lime, amounting to some 2 to 4 tons per day during the hard water season which should have a value of approximately $20,000 per year. No credit is given in this economic comparison. The filter cake, in the case where lime values are not recovered, is composed primarily of calcium carbonate. It could be worth approximately $1.50 per ton to local cattle ranchers as another water treatment plant in the area has made such an arrangement. The ranchers pick up the filter cake at the plant in their trucks.

In order to compare the magnesium process with the present alum process, sludge dewatering using a filter press is included. In addition, as increased clarifier size is required for the alum process but not for the magnesium process, these additional costs are noted as plant additions.

The capital cost for the filter press and appurtenances has been estimated at $1,250,000 and the plant additions at $298,000 for a total capital cost of $1,548,000. These cost estimates are derived from the Smith and Gillespie

Report of 1973.[15] The costs can be summarized as:

	$/year	$/ton*
Capital Amortization ($1,548,000 @ 6% for 25 years)	119,703	54.60
Maintenance @ 2%	30,000	14.13
Operation of Press	20,000	9.13
Power (Press)	5,000	2.28
Chemicals (Press)	32,850	15.00
Sludge Hauling to Suitable Landfill	35,000	15.98
Present Chemical Cost	94,170	
TOTAL COST	$337,683	$111.12

*Based on 22 MGD production, 6 tons of dry solids per day.

It should be emphasized that sludge hauling costs can be expected to increase in the future as haul distances become longer and hauling costs increase.

Summarizing these costs:

	Annual Cost
Magnesium Process	
With recalcination	$217,010
Purchase lime and CO_2	$270,204
Alum Process	
Including plant improvements and sludge pressing	$337.683

Energy Considerations

Lime recalcination requires considerable on-site energy, thus, careful consideration is in order. The following facts would appear to apply:

A. Commercial quicklime, used in larger tonnage than any other water treatment chemical, requires the following energy-consuming operations for its manufacture:

1) Mining of limestone or marble in quarry
2) Transporting to kiln
3) Crushing and grinding before burning
4) Burning in vertical shaft or rotary kilns
5) Bulk shipment (600 miles in Melbourne's case)
6) Unloading and shipment to the water plant.

B. Recalcining calcium carbonate sludge on-site would:

1) Eliminate 1, 2, 3, 5 and 6.
2) The additional heat required to evaporate the moisture from the filter or centrifuge cake is only slightly higher than for (4).
3) Produces more than sufficient CO_2 in the stack gas to carbonate the plant's finished water, for stabilization and sludge carbonation, thus making an important energy saving.
4) Eliminates the need for hauling dewatered sludge for ultimate disposal.

This very simplistic approach to evaluating the energy balance of the two alternatives would weigh heavily in favor of on-site lime recovery.

SECTION VI

REFERENCES

1. Eidsness, F. A. and A. P. Black. Carbonation of Water Softening Plant Sludge. J.AWWA. 49:1343 (1967).

2. Black, A. P. Split-Treatment Water Softening At Dayton. J.AWWA. 58:1:97 (January 1966).

3. Black, A. P., B. B. Shuey and P. J. Fleming. Recovery of Calcium and Magnesium Values From Lime-Soda Softening Sludges. J.AWWA. 63:(10):616 (October 1971).

4. Thompson, C. G., J. E. Singley and A. P. Black. Magnesium Carbonate - A Recycled Coagulant. J.AWWA. 64:(1):11 (January 1972).

5. Thompson, C. G., J. E. Singley and A. P. Black. Magnesium Carbonate - A Recycled Coagulant, Part II. J.AWWA. 64:(1):94 (February 1972).

6. Department of Public Utilities (Gainesville, Florida). Magnesium Carbonate, A Recycled Coagulant For Water Treatment. Environmental Protection Agency. Washington, D. C. Publication Number 12120 ESW. June 1971. 107 p.

7. Sperry, W. A. The Lime Softening Of Water And The Use Of The Sludge As An Aid Thereto. J.AWWA. 6:215 (June 1919).

8. Hartung, H. O. Experience With Up-Flow Type Basins. Water & Sewer Works. 1:91 (January 1944).

9. McCauley, R. F. and R. Eliassen. Accelerating Calcium Carbonate Precipitation in Softening Plants. J.AWWA. 52:106 (May 1955).

10. Tuepker, J. L. and H. O. Hartung. Effect of Accumulated Lime-Softening Slurry on Magnesium Reduction. J.AWWA. 52:106 (January 1960).

11. Lawrence, R. W. Equilibrium And Kinetics For The Carbonation of Magnesium Hydroxide Slurries. Research and Development Progress Report #754. U. S. Department of Interior. (December 1971).

12. Riehl, M. L., H. H. Weiser and R. T. Rheins. Effect of Lime Treated Water Upon Survival Of Bacteria. J.AWWA. 44:466 (May 1952).

13. Chaudhure, Maley and R. S. Engelbrecht. Removal Of Viruses From Water By Chemical Coagulation And Flocculation. J.AWWA. 62:563 (September 1970).

14. Flentje, M.E. Calcium And Magnesium Hydrates. J.AWWA. 17:253 (1927).

15. Smith & Gillespie Consulting Engineers, Inc. (Jacksonville, Florida). Water Treatment Facilities Report, Melbourne, Florida. (February 1973).

SECTION VII

APPENDICES

		Page
A.	DATA SHEETS TO SHOW TYPICAL RESULTS, MONTGOMERY, ALABAMA	97
B.	VACUUM FILTER TESTS, MONTGOMERY, ALABAMA	117
C.	ROUTINE DATA SHEETS, MELBOURNE, FLORIDA	127
D.	SUMMARY OF DAILY AVERAGE RESULTS, MELBOURNE, FLORIDA	131
E.	E.P.A. ANALYSIS FOR HEAVY METALS AND COMMENTS, MELBOURNE, FLORIDA	133
F.	PHOTOGRAPHS OF THE MONTGOMERY AND MELBOURNE FACILITIES	137

APPENDIX A

DATA SHEETS TO SHOW TYPICAL RESULTS, MONTGOMERY, ALABAMA

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/2 0000	10.1	116	30	86	11.7	8.8	93	87	79	4.7	1.7	7.55	16000	12	6.0'	8.8	71	10	4.2
0200	10.15	118	30	88	11.65	8.9	99	90	81	5.3	1.8	7.55	16600	10	5.5'	8.85	75	10	4.2
0400	10.1	112	29	83	11.7	8.9	95	87	80	5.0	1.9	7.6	16100	10	5.3'	8.9	79	10	4.2
0600	10.05	107	27	80	11.7	9.0	93	86	78	4.6	1.7	7.6	15900	10	5.0'	9.0	80	10	4.2
0800	10.2	120	24	98	11.55	9.2	96	89	82	6.0	1.9	7.6	16100	10	5.0'	9.05	78	10	4.2
1000	10.2	108	28	80	11.6	9.0	96	89	82	5.8	1.9	7.7	15600	10	5.0'	8.95	78	10	4.2
1200	10.4	80	28	52	11.65	8.8	96	90	84	5.9	2.0					8.9	76	10	4.2
1400	10.1	160	34	126	11.05	8.7	110	100	88	6.5	1.9			12	Full	8.8	82	10	4.2
1600	10.1	130	30	100	11.5	9.0	115	100	85	6.0	2.0	7.7	15600		4.2'	8.8	72	10	4.2
1800	10.0	96	30	66	11.6	8.7	100	95	82	5.0	2.0	7.75	15400		Full	8.8	72	10	
2000	10.1	100	30	70	11.5	8.5	105	95	84	4.5	2.0	Not Taken Because of Pump			Full	8.7	70	10	4.2 / 4.0
2200	10.2	100	30	70	11.65	8.0	98	90	80	3.8	1.5	7.7	15600	Full	3.8'	8.4	72	10	4.0 / 3.0
3/3 0000	10.35	82	30	52	11.75	9.0	90	87	77	4.5	1.8	7.8	15400	Max.	2.0'	8.8	74	10	2.8 / 3.0
0200	10.4	82	28	54	11.6	9.5	90	82	76	5.5	1.8	7.8	15200	5	1.5'	9.1	73	10	3.0 / 3.2
0400	10.4	82	28	54	11.54	9.4	87	82	75	4.8	1.4	7.8	15100	5	1.2'	9.1	73	10	3.4
0600	10.35	80	26	54	11.7	9.1	85	81	74	4.6	1.5	7.8	15100	4	1.0'	9.0	71	10	3.6
0800	10.2	88	26	62	11.5	9.3	90	86	80	6.0	1.7	7.4	16700	6	2.6'	9.15	64	10	4.0
1000	10.4	86	30	56	11.65	8.5	96	88	80	5.5	1.9	7.35	17200	8	3.6'	9.0	70	11	3.5

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #3		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/3																			
1200	10.2	90	28	62	11.5	8.8	94	88	82	5.8	1.9	7.85	15100	8	4.5'	8.65	72	11	3.5
1400	10.1	78	28	50	11.7	9.2	98	92	80	6.2	1.9	7.9	14900	8	6.5'	8.8	70	11	3.7
1600	10.1	79	28	51	11.65	9.0	96	90	82	6.0	2.0	7.8		All	Full	8.8	71	11	3.7
1800	10.2	78	27	51	11.7	9.0	98	96	80	5.8	1.8	Not Taken		All	5.5'	8.9	72	11	3.7
2000	10.2	80	30	50	11.65	9.0	100	92	78	5.0	1.8	7.8	14500	All	4.8'	8.9	74	11	3.7
2200	10.2	85	30	55	11.6	9.0	105	92	78	4.8	1.8	7.8	14400	All	4.8'	8.9	72	11	3.7/4.0
3/4																			
0000	10.3	82	30	52	11.7	9.0	102	92	80	5.0	1.8	7.9	13500	All	4.8'	8.9	74	11	4.0
0200	10.4	80	30	50	11.75	9.0	97	94	82	5.5	1.9	8.0	13300	Max.	5.2'	9.0	78	11	4.0
0400	10.35	82	30	52	11.7	9.0	98	94	82	5.5	1.7	7.9	13500	Max.	5.6'	9.0	78	11	4.0
0600	10.3	78	30	48	11.75	8.9	90	87	78	5.3	1.5	8.0	13000	Max.	6.1'	8.9	76	11	4.0/3.5
0800	10.25	86	36	50	11.7	9.0	100	90	82	5.1	1.6	8.1	13000	Max.	6.6'	8.9	70	12	3.8
1000	10.3	80	34	46	11.7	9.0	98	90	80	3.0	1.5	8.05	12700	Max.	6.5'	9.3	66	12	4.0
1200	10.1	78	30	48	11.55	9.0	100	50	80	3.0	1.3	8.05	12200	Max.	6.8'	8.9	70	12	4.0
1400	10.15	76	32	44	11.7	9.1	100	92	80	3.8	1.4	8.1	12000	Max.	6.8'	8.85	74	12	4.0
1600	10.25	80	30	50	11.7	9.0	100	90	78	4.0	1.8	8.0	12000	Max.	6.7'	8.8	74	12	4.0
1800	10.2	82	30	52	11.7	9.0	100	92	78	4.0	2.0	8.1	11500	Max.	Full	8.8	72	12	4.0
2000	10.2	84	32	52	11.7	9.0	100	90	80	3.8	2.0	8.0	11000	Max.	Full	8.8	72	12	4.0/4.4
2200	10.3	89	32	57	11.75	8.9	95	90	80	3.0	1.0	7.2	12200	Max.	6.0' Full	8.8	70	12	4.4

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/5																			
0000	10.4	70	32	48	11.65	9.1	95	92	78	3.0	1.4	8.1	13500	Max	Full	9.0	70	12	4.4
0200	10.35	70	32	38	11.6	8.9	95	90	80	3.2	1.2	7.9	14400	Max	Full	9.0	70	12	4.4
0400	10.35	70	32	38	11.7	8.9	95	90	80	3.3	1.2	8.0	12200	Max	7.0'	8.9	72	12	4.4
0600	10.35	70	34	36	11.7	8.8	94	91	82	3.4	1.4	8.1	10000	Max	7.0'	8.8	72	12	4.4
0800	10.25	72	37	35	11.7	8.7	90	89	76	3.2	1.2	8.0	11500	Max	Full	8.8'	72	12	4.4
1000	9.9	118	42	76	11.65	8.8	90	91	76	3.5	1.1	7.5		10	4.0'	3.8	70	12	4.4
1200	9.95	92	40	52	11.7	8.7	93	92	76	2.2	1.1	7.35	16100	10	2.0'	8.8	70	12	4.4
1400	10.0	100	47	53	11.6	9.2	91	90	74	3.6	1.1	7.3	16200	9.5	2.5'	9.0	68	12	4.4
1600	10.0	101	44	57	11.7	9.1	93	91	72	3.0	1.4	7.4	17900	9.5	3.0'	9.1	65	12	4.4
1800	10.0	100	48	52	11.7	9.0	95	90	74	3.2	1.1	7.4	16800	Max	3.8'	8.9	68	12	4.4
2000	10.0	102	50	50	11.65	9.0	92	90	75	3.2	1.2	7.5	17000	Max	4.0'	8.9	65	12	4.4
2200	10.0	100	52	48	11.7	9.0	94	90	75	3.2	1.1	7.5	16900	Max	5.5'	8.9	68	12	4.4
3/6																			
0000	10.1	96	32	64	11.85	8.9	94	88	78	3.2	1.2	7.5	14800	Max	5.8'	8.9	68	12+	4.0
0200	10.15	94	30	64	11.7	9.0	92	88	78	3.5	1.2	7.5	14900	11	4.8'	8.9	68	12+	4.0
0400	10.1	104	30	74	11.4	9.0	88	86	76	3.8	1.4	7.45	14900	9	2.8'	8.9	67	12+	4.0
0600	10.15	102	28	74	11.7	8.9	84	83	73	3.5	1.2	7.5	15100	8	4.0'	8.9	65	12+	4.0
0800	10.1	111	32	79	11.65	8.6	85	84	73	3.6	1.4	7.7	12600	8	4.0'	8.8	64	12	4.0/3.7
1000	10.1	110	30	80	11.4	8.6	86	84	74	3.4	1.3	7.65	13000	8	4.0'	8.7	66	12	3.7

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/6 1200	10.1	114	32	82	11.7	8.7	91	88	78	3.7	1.3	7.4	14000	8	3.9'	8.7	65	12	3.7
1400	Working on Sludge Control Valve																		
1600	10.45	69	31	38	11.7	8.6	91	88	79	3.5	1.2	7.2	15400	8	1.5'	8.6	68	12	3.3
1800	10.3	55	40	15	11.4	8.6	87	87	83	4.2	1.4	7.2	15900	8	6.2'	8.8	73	12	3.3
2000	10.4	65	39	26	11.7	8.8	87	87	79	4.5	1.5				6.5'	8.8	65	12	3.3
2200	10.35	69	38	31	11.7	7.7	88	88	77	4.2	1.2				6.5'	7.95	71	12	3.3
3/7 0000	10.4	58	34	24	11.75	8.8	88	88	76	4.1	1.2					8.4	70	14	3.3
0200	10.45	54	32	22	11.8	8.9	89	89	74	3.5	1.2					8.7	68	14	3.0
0400	10.45	62	30	32	11.7	8.9	88	86	74	3.9	1.3					8.8	68	14	3.0
0600	10.45	64	30	34	11.75	8.9	88	86	74	3.5	1.2					8.8	69	14	3.0
0800																			
1000	10.4	58	29	29	11.7	8.8	91	90	73	5.0	1.7					8.7	70	14	3.3
1200	10.3	67	30	37	11.75	9.0	85	85	71	5.0	1.8					8.75	66	14	3.5
1400	10.35	65	29	36	11.7	8.9	88	84	68	4.6	1.5					8.7	68	14	3.5
1600	10.35	60	28	32	11.5	9.0	88	82	74	7.3	1.7	7.55	14900			9.0	68	14	3.5
1800	10.3	60	30	30	11.7	9.1	89	80	70	6.8	1.7					8.9	64	14	3.5
2000	10.3	60	30	30	11.7	8.7	90	88	74	6.7	1.6					9.0	66	14	3.5
2200	10.4	62	32	30	11.75	9.1	90	88	74	5.6	1.5					8.9	68	14	3.5

1 TH-Total Hardness
2 CH- Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/8																			
0000	10.45	66	34	30	11.7	8.9	87	82	68	5.4	1.7					8.9	64	14+	3.5
0200	10.35	68	32	36	11.7	9.1	86	84	70	5.1	1.6					9.0	66	14	3.5
0400	10.4	66	32	34	11.75	9.1	90	86	71	4.9	1.3					9.0	68	14+	3.8
0600	10.45	60	30	30	11.7	9.2	92	91	75	4.4	1.8					9.1	70	14+	4.0
3/13																			
1600	8.65	80	26	54	11.6	9.7	106	102	90	9.5	6.4	7.05	15900	11	3.5'	9.1	80	14	2.0
1800	9.8	98	30	68	11.5	9.8	100	94	84	9.0	5.2	8.1	9,800	10	2.9'	96	64	14	3.0
2000	8.8	90	30	60	11.55	9.4	108	108	90	7.2	4.0	7.1	27,000	11	3.6'	9.3	70	14	2.5
2200	8.3	72	30	42	11.6	8.8	108	108	90	9.0	5.0	6.8	6000	11	4.3'	8.8	88	14	2.5
3/14																			
0000	8.9	180	37	143	11.6	9.7	113	112	91	6.0	4.0	7.3	24400	14	3.0'	9.6	75	14	3.3
0200	9.6	108	40	68	11.4	9.7	110	108	85	6.8	4.0	7.7	20300	12	3.0'	9.6	75	14	4.0
0400	9.7	100	40	60	11.4	9.4	104	104	85	6.8	3.5	7.6	17100	14	4.5'	9.3	75	14	4.0
0600	9.75	112	47	66	11.65	9.3	113	108	85	7.0	3.1	7.6	16200	14	4.5'	9.15	70	14	4.0
0800	9.75	110	42	68	11.65	9.2	113	109	84	7.2	2.9	7.65	16500	14	4.5'	9.1	76	14	4.0
1000	9.5	130	36	94	11.6	9.2	112	107	88	7.8	2.6	7.75	14300	10.5	5.3'	9.15	78	11	3.5
1200	9.9	96	44	52	11.7	9.3	110	106	86	7.3	2.9	7.6	14000	10.5	6.0'	9.15	76	14	4.0
1400	9.85	112	52	60	11.45	9.4	107	107	89	8.0	2.8	7.5	16100	10.5	5.8'	9.1	77	14	4.0
1600	9.9	110	50	60	11.6	9.4	106	105	86	8.5	2.7	7.4	15800	10.5	3.9'	9.2	72	14	4.0
1800	9.8	99	47	52	11.6	9.3	102	102	85	8.7	2.5	7.55	15200	10	Full	9.0	64	14	4.0 / 4.2

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/14 2000	10.0	102	48	54	11.6	9.2	100	99	83	9.4	2.9	7.5	15400	10	6.5'	8.9	64	14	4.2
2200	10.1	106	50	56	11.6	9.1	101	101	82	9.9	3.0	7.5	15200	10	6.5'	9.0	63	14	4.2
3/15 0000	10.2	80	46	34	11.7	9.2	100	100	84	9.9	2.5	7.5	14400	10	6.5'	9.2	72	14	4.2
0200	9.8	64	35	29	11.6	9.3	99	97	81	15.0	3.3	7.5	14500	10	6.5'	9.3	78	14	4.2
0400	9.9	98	50	48	11.65	9.4	101	100	83	20	2.5	7.5	14500	14	6.3'	9.1	75	14	4.2
0600	10.2	78	48	30	11.7	8.6	105	104	87	15	2.6	7.65	13300	14	6.5'	8.85	85	14	3.3
0800	10.25	79	49	30	11.75	9.1	105	104	91	20	2.2	7.85	13200	14	6.5'	9.0	83	14	3.6
1000	10.0	134	54	80	11.5	9.4	107	105	90	20	2.0	7.8	12400	11	5.9'	9.0	84	14	3.6 4.2
1200	10.1	126	48	78	11.7	9.0	112	109	86	25	2.0	7.3	12900	10.5	4.0'	8.9	79	14+	4.2
1400	10.0	127	50	77	11.7	8.5	119	116	88	20	2.4	7.35	15300	10.5	5.0'	8.8	85	14+	4.0
1600	10.1	112	56	56	11.6	8.6	116	112	81	19	1.8	7.5	14300	10.5	6.0'	8.7	81	14	4.2
1800	10.1	115	51	64	11.6	8.8	116	112	83	18	1.7	7.5	14400	10	5.0'	8.7	77	14	4.2
2000	10.1	121	48	73	11.6	9.0	118	114	86	18	1.5	7.6	14600	10	4.2'	8.7	72	14	4.0
3/16 0000	10.1	118	50	68	11.7	9.1	110	109	80	20	1.5	7.7	14500	10	4.5'	8.8	80	14	4.0
0200	10.0	115	48	67	11.6	9.0	115	110	90	21	1.5	7.65	14000	10	6.5'	8.9	81	14	4.0
0400	10.0	135	58	77	11.7	8.7	120	115	90	20	1.3	7.65	14200	10	6.5'	8.6	85	14	3.5
0600	10.0	130	52	78	11.7	8.4	119	119	95	18	1.4	7.65	14000	12	5.8'	8.6	90	14	3.3
0800	10.1	116	48	68	11.8	8.7	109	109	88	18	1.5	7.65	14200	12	3.5'	8.7	91	14	3.6

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/16																			
1000	10.05	124	46	78	11.65	8.7	111	111	88	18	1.4	7.5	15700	11	4.5'	8.7	80	13	3.2
1200	10.15	122	47	75	11.7	8.7	110	108	85	15	1.3	7.35	15100	15	3.8'	8.7	78	13	3.2
1400	10.15	118	47	71	11.65	8.8	111	110	87	15	2.2	7.55	15500	14	4.3'	8.6	79	13	3.2
1600	10.1	121	51	70	11.6	8.8	110	107	82	14	1.4	7.1	16400	14	4.5'	8.7	76	13	3.0
1800	9.9	120	50	70	11.5	8.4	110	108	95	10	1.3	7.3	15900	14	4.2'	8.7	75	13	3.0 / 2.7
2000	10.1	122	51	73	11.5	8.4	112	110	90	10	1.7	7.25	16000	10	4.0'	8.7	77	13	2.7
2200	10.1	118	54	64	11.5	83	115	114	87	9	2.0	7.3	15800	10	3.5'	8.6	80	13	2.7 / 2.2
3/17																			
0000	10.25	120	48	72	11.6	7.3	134	114	90	5.8	1.7	7.1	16600	9	3.0'	8.3	88	10	2.0
0200	10.3	100	50	50	11.6	8.5	124	108	85	8.5	1.9	7.1	14600	8	2.0'	8.5	88	10	2.0
0400	10.3	106	50	56	11.6	9.1	112	108	85	14	1.8	7.35	16500	8	2.6'	8.6	86	10	2.0
0600	10.3	114	50	64	11.6	9.3	110	100	88	17	1.4	7.2	16400	8	3.6'	8.9	67	10	2.0
0800	10.2	94	48	46	11.65	9.6	97	95	80	18	1.5	7.7	15100	5.5	4.5'	9.2	78	10	2.0
1000	10.3	104	56	48	11.65	9.1	108	108	87	17	1.6	7.25	15600	5.5	4.0'	9.0	77	12	3.5
1200	10.25	110	48	62	11.6	8.4	112	106	88	12	1.7	7.3	16300	5.5	4.8'	8.6	82	12	3.5 / 2.5
1400	10.1	114	50	64	11.65	8.7	110	110	89	10	1.5	7.3	16200	5.5	5.2'	8.6	80	12	2.5 / 2.0
1600	10.25	112	48	64	11.5	9.0	107	106	85	9	1.6	7.2	16100	6.0	4.5'	8.7	77	12	2.1
1800	10.1	118	52	66	11.5	9.1	107	104	81	8.5	2.0	7.2	16000	8.0	5.0'	8.8	75	12	2.1 / 2.4
2000	10.1	126	52	74	11.6	8.9	109	107	82	8.0	2.0	7.25	16200	9.0	3.0'			12	2.4

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH [1]	CH [2]	MH [3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/17 2200	White Elephant on Strike - Corrected at 2230 (From 2130 to 2230)																		
3/18 0000	9.8	114	42	72	11.4	8.2	106	100	86	6.3	2.2	7.4	15900	11	3.4'	8.8	80	12	2.4
0200	10.2	120	54	66	11.6	7.8	106	09	78	5.5	2.4	7.3	1600	11	4.4'	8.4	98	12	1.9
0400	10.15	124	52	72	11.6	8.8	102	98	80	5.4	2.5	7.3	1600	11	5.0'	8.6	90	12	1.0
0600	10.2	112	50	62	11.6	9.4	100	92	74	6.7	2.6	7.4	1600	11	4.1'	8.9	62	12	1.0
0800	9.7	106	40	66	11.6	9.5	99	96	75	5	2.2	7.4	15600	11	4.8'	9.1	63	12+	1.0 / 2.0
1000	10.2	110	46	64	11.5	9.1	105	99	78	6	2.3	7.3	15200	11	4.0'	9.0	64	12+	2.0 / 2.5
1200	10.3	92	50	42	11.5	8.6	115	110	78	5.3	2.1	7.4	15400	11	6.0'	8.8	62	12	2.5 / 2.0
1400	10.35	92	50	42	11.6	8.7	115	110	88	5.5	2.0	7.25	15600	11	6.8'	8.7	80	12	2.0
1600	10.3	93	52	41	11.4	8.7	110	106	82	5.1	1.9	7.2	15100	10	6.5'	8.7	82	12	2.0
1800	9.9	97	47	50	11.4	9.0	108	106	80	5.0	1.8	7.25	15700	9	4.5'	8.8	77	12	2.0 / 2.3
2000	10.0	101	43	58	11.6	9.0	106	100	75	4.8	2.0	7.25	16200	9	3.0'	8.9	70	12	2.3 / 3.0
2200	10.2	109	42	67	11.4	8.9	105	98	76	4.5	1.8	7.35	16400	8.5	3.0'	9.0	71	12	3.0
3/19 0000	9.9	116	46	70	11.3	9.6	130	98	95	5.8	2.5	7.4	17600		2.0'	9.4	65	12	3.0
0200	10.05	102	40	62	11.15	9.3	100	90	78	4.9	2.5	7.35	18500		3.0'	9.4	68	12	3.0
3/21 1400	9.95	142	34	108	11.7	7.8	82	81	74	6.0	3.0	7.5	16900	15	5'			9	1.5
1600	10.0	134	40	94	11.6	9.4	88	84	79	6.2	2.6	7.7	16200	14.5	5.5'			9 / 10	1.2 / 2.0
1800	10.0	138	42	96	11.5	9.7	79	75	70	10	3.0	7.7	15100	14.5	5.5'			10 / 12	2.0 / 3.0

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/21 2000	10.0	140	44	96	11.55	9.3	81	77	72	11	2.5	7.7	15300	14.5	5.5'			12	3.7
2200	10.0	120	42	78	11.6	9.2	85	81	77	10	2.7	7.5	15600	15	6.0'			12	3.7
3/22 0000	9.85	138	40	98	11.5	8.8	92	84	84	7.5	1.9	7.7	14700	15	7.0'	8.85	70	13	4.0
0200	9.1	132	38	94	11.5	9.05	90	84	82	7.4	1.7	7.6	14900	15	6.5'	8.9	72	13	4.0 / 3.7
0400	10.0	130	40	90	11.6	8.5	90	82	80	6.9	1.7	7.6	14600	15	6.0'	8.8	72	13	3.0 / 2.9
0600	10.05	130	42	88	11.6	8.9	90	86	82	9.0	1.6	7.7	15200	15	6.2'	8.6	10	13	2.9
0800	10.0	130	46	84	11.7	9.0	81	78	73	6.0	1.5	7.2	16300	15	6.0'	8.6	71	13	2.9
1000	10.0	128	42	86	11.55	9.15	83	78	70	5.4	1.5	7.4	14300	15	5.5'	8.8	70	13	2.9
1200	10.1	130	45	85	11.6	9.3	85	80	72	5.5	1.6	7.7	14700	15	5.4'	8.9	72	13	2.9 / 3.5
1400	10.0	127	41	86	11.5	9.2	83	78	71	7.5	2.0	7.4	14400	15	5.6'	8.5	70	13	3.5
1600	10.0	126	38	88	11.5	8.8	80	74	75	9.0	2.0	7.5	13900	15	0.0'	8.8	69	12+	3.4
1800	10.0	124	36	88	11.5	8.6	94	80	76	7.5	1.5	7.5	13600	15	6.0'	8.7	70	12	3.4 / 3.0
2000	10.0	134	42	92	11.5	8.4	84	81	74	8.5	2.0	7.5	13600	15	5.5'	8.6	69	12	3.0 / 2.0
2200	10.0	118	36	82	11.5	9.1	79	76	76	8.0	1.7	7.6	13200	15	6.5'	8.9	71	12	2.0
3/23 0000	10.0	148	40	108	11.6	9.3	90	80	60	8.3	1.5	7.55	15000	15	6.8'	9.1	64	12	2.0
0200	10.0	140	44	96	11.6	9.3	90	78	60	7.2	1.4	7.45	14500	15	5.1'	9.0	68	12	2.0
0400	10.1	144	40	104	11.55	9.3	98	80	66	14.0	2.0	7.5	13800	15	3.8'	9.2	64	12	2.0
0600	10.0	140	40	100	11.6	9.3	82	72	70	7.3	1.4	7.5	13200	15	4.6'	9.2	64	12	2.0

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/23																			
0800	9.9	130	40	90	11.6	9.5	88	75	72	4.0	1.5	7.35	13500	15	6.6'	9.2	57	12	2.0
1000	9.8	210	45	165	11.6	9.15	95	82	70	6.0	1.5	7.4	12600	15	4.5'	9.2	59	12	3.0
1200	10.0	140	42	98	11.6	8.8	93	82	70	6.0	1.5	7.4	12800	15	Foamy	9.2	59	12	2.0
1400	10.0	140	40	100	11.6	9.0	88	84	68	6.5	1.0	7.4	12900	15	2.5'	9.2	58	12	2.0
1600	10.05	118	40	78	11.6	9.0	97	94	64	8	1.8	7.6	13700	15	2.1'	9.0	58	12	2.0
1800	10.1	140	40	100	11.5	9.0	94	88	69	9	1.9	7.5	14100	15	1.5'	8.9	62	12	2.0
2000	10.1	136	40	96	11.55	9.2	90	84	63	9	1.9	7.5	14000	15	3.0'	9.1	59	12	2.0
2200	10.1	134	38	96	11.6	9.1	96	86	67	8	1.7	7.45	13900	15	3.5'	9.0	60	12	2.0 / 2.5
3/24																			
0000	10.1	130	36	94	11.5	9.0	95	84	66	8.5	1.5	7.5	14200	15	4.0'	9.0	62	12	2.6
0200	10.0	137	37	100	11.5	8.9	101	89	66	7.0	1.5	7.5	13600	15	4.5'	8.85	57	12	2.7
0400	10.0	137	38	99	11.55	8.7	97	86	68	5.5	1.1	7.4	14100	15	5.0'	8.5	61	12	2.5
0600	10.0	136	35	101	11.5	8.8	99	85	67	5.7	1.2	7.45	14000	15	5.3'	8.5	60	12	2.5
0800	10.0	132	35	97	11.55	8.7	98	86	62	5.2	1.5	7.4	13800		4.8'	8.6	64	12	2.5
1000	10.0	135	35	100	11.5	8.6	96	86	64	5.5	1.5	7.4	13600		4.5	8.4	62	12	2.5
1200	9.9	135	40	95	11.5	8.7	95	85	60	5.0	1.0	7.4	13800		4.0'	8.6	65	12	2.5
1400	10.0	138	40	98	11.55	8.6	98	85	64	5.5	1.5	7.4	14000		4.0'	8.6	65	12	2.5
1600	10.15	122	38	84	11.55	8.6	98	85	64	5.5	1.6	7.4	14800	Max	6.5'	8.6	65	12	2.5 / 2.0
1800	10.2	126	36	90	11.55	8.7	90	85	72	5.7	1.6	7.45	14800	Max	6.6'	8.6	67	12	2.0

1 TH-Total Hardness
2 CH-Calcium hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/24 2000	10.2	124	36	88	11.5	8.6	90	85	68	6.0	1.7	7.4	14700	Max	7.0'	8.7	58	12	2.0 1.8
2200	9.9				11.5	8.8	90	82	67	6.0	1.4	7.4		Max	5.5'			12	1.8
3/25 0000	9.95	126	32	94	11.5	9.0	88	81	64	5.9	1.3	7.6	13500	Max	1.5'	8.9	53	12	1.8 2.0
0200	9.9	124	34	90	11.5	8.9	90	83	65	5.8	1.2	7.5	13700	15	2.0'	8.9	49	12	2.0 2.3
0400	9.9	122	30	92	11.5	9.2	91	86	70	5.0	1.0	7.5	14100	15	2.0'	8.9	51	12	2.3 2.8
0600	9.95	126	32	94	11.55	8.9	92	86	68	4.5	0.8	7.5	13600	15	2.2'	8.9	50	12	2.8
0800	9.9	130	35	95	11.5	8.8	92	84	65	4.5	1.5	7.5	13500	15	3.0'	8.8	52	12	2.8
1000	9.9	130	32	98	11.5	8.9	94	84	66	4.5	1.0	7.5	14000	15	2.0'	8.9	54	12	2.8
1200	10.1	128	30	98	11.5	9.0	92	84	64	4.8	1.0	7.4	13800	15	2.0'	8.9	58	12	3.0
1400	10.0	130	30	100	1.55	9.0	92	86	65	5.0	1.0	7.4	13800	15	2.0'	9.2	58	12	3.4
1600	10.0	120	28	92	11.55	9.2	87	85	75	6.0	1.4	7.45	13700	15	4.5'	9.2	68	12	3.5
1800	10.05	126	28	98	11.6	8.6	87	83	72	6.5	1.4	7.55	13600	15	4.3'	8.9	67	12	3.5
2000	10.0	128	32	96	11.6	8.8	88	84	76	5.8	1.2	7.5	14600	15	2.5'	8.9	70	12	3.5
2200	10.0	128	36	92	11.6	8.9	89	85	80	5.5	1.2	7.6	14900	8	1.5'	8.9	70	12	3.5
3/26 0000	10.0	119	34	85	11.5	9.0	90	86	76	5.2	1.0	7.45	14800	15	2.0'	8.9	72	12	3.5
0200	10.0	125	34	91	11.5	8.9	95	86	76	5.2	1.2	7.5	14700	15	3.0'	8.9	73	12	3.5
0400	9.9	132	36	96	11.55	8.7	99	88	78	5.2	1.2	7.4	15000	15	3.5'	8.8	75	12	3.5
0600	10.0	127	34	93	11.5	8.7	102	87	72	5.0	1.0	7.4	14600	15		8.7	69	12	3.3

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM PLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/26 0800	9.9	164	52	112	11.6	8.7	104	87	94	4.5	1.0	7.4	16100	15		8.4	66	12	3.3
1000	9.95	135	59	76	11.65	8.8	90	88	73	2.9	0.8	7.4	14500	15		8.85	68	12	3.0
1200	9.9	120	41	79	11.3	9.25	90	85	68	5.5	1.2	7.4	14200	15	4.0'	9.2	64	12	3.0
1400	9.9	121	61	60	11.35	8.7	86	83	68	6.8	1.2	7.45	14300	15	3.0'	8.75	62	12	3.15
1600	10.0	130	36	94	11.6	7.9	82	73	68	7.6	1.6	7.5	14300	14	4.2'	8.5	66	12+	3.2 / 2.0
1800	10.0	122	34	88	11.7	8.1	80	72	68	6.8	1.6	7.6	14200	14	5.5'	8.4	64	12+	2.0
2000	10.0	128	34	94	11.7	9.3	87	80	73	6.0	1.4	7.6	13900	14	5.0'	8.6	59	12	2.0 / 2.5
2200	10.0	132	32	100	11.65	9.5	90	88	76	6.0	1.4	7.6	13600	14	5.0'	8.8	66	12	2.5 / 3.0
3/27 0000	10.0	129	37	92	11.5	9.5	90	86	73	6.1	1.4	7.6	13800	15		9.0	62	12	3.0 / 3.5
0200	9.95	127	39	88	11.6	9.4	93	86	74	6.4	1.6	7.55	13600	15		9.2	59	12	4.0
0400	10.0	130	37	93	11.6	9.2	94	85	73	5.2	1.3	7.6	13800	15		9.0	61	12	4.0
0600	9.0	132	36	96	11.5	8.8	96	87	76	4.5	1.0	7.55	14000	15		8.9	65	14	4.0
0800	10.0	122	36	86	11.6	8.8	98	96	80	6.9	0.9	7.55	14400	15	2.5'	8.8	68	14	4.0
1000	10.0	130	34	96	11.55	8.9	96	92	84	5.5	0.9	7.45	14500	15	4.0'	8.7	62	14	4.0
1200	10.0	138	42	96	11.6	8.8	98	90	78	9.2	1.0	7.5	14200	15	3.11'	8.8	72	14	4.0
1400	10.0	126	36	90	11.5	9.0	98	90	80	8.5	0.9	7.45	14400	15	3.3'	8.8	72	14	4.0
1600	9.95	130	36	94	11.6	8.8	91	88	80	9.0	0.9	7.5	14200		0.8'	8.8	75	15	4.0
1800	10.0	130	36	94	11.6	9.0	96	91	82	9.5	1.5	7.45	14100		1.2'	8.8	73	15	4.0

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1 pH	TH[1]	CH[2]	MH[3]	RAPID MIX #2 pH	MAGNESIUM FLUME pH	TH	CH	ALK	TURB	ACID TURB	CARBONATED SLUDGE pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	EFFLUENT FILTER #5 pH	ALK	CO_2 SETTING (cfm) #1	#2
3/27 2000	10.0	132	34	98	11.6	8.9	91	88	78	9	1.2	7.4	14200		0.5'	8.9	68	15	4.0
2200	10.0	132	34	98	11.6	9.1	88	86	76	9	1.2	7.5	14200		0.8'	8.9	68	15	4.0
3/28 0000	10.1	148	65	83	11.75	8.65	88	86	76	5.8	0.8	7.3	14300			8.7	67	15	4.0
0200	9.9	112	43	69	11.6	8.7	90	88	75	5.6	1.2	7.35	13800			8.7	75	15	3.5
0400	9.9	118	42	76	11.6	8.6	91	87	75	6.8	1.2	7.4	14000			8.75	70	15	3.5
0600	9.9	119	41	78	11.6	8.75	90	88	78	5.8	1.0	7.4	14000			8.85	70	15	3.15
0800	10.0	132	38	94	11.6	8.8	98	84	80	8.0	1.3	7.55	14700	Max	Full	8.9	64	15	3.15
1000	10.0	130	38	92	11.6	8.8	90	80	74	6.1	0.8	7.45	14600	Max	4.6'	8.9	64	15	3.15
1200	9.9	148	34	114	11.6	8.8	88	80	68	5.0	0.9	7.4	14500	Max	4.6'	8.9	64	15	3.15
1400	9.95	128	38	90	11.8	8.8	108	86	74	9.2	0.9	7.4	13500	Max	5.0'	9.0	72	15	3.15
1600	10.1	145	42	103	11.7	9.1	82	75	75	7.5	1.0	7.4	13400		5.0'	8.9	64	15	3.15
1800	10.0	140	40	100	11.6	9.0	82	75	72	7.0	1.0	7.4	14000		5.5'	8.9	66	15	3.15
2000	10.0	140	40	100	11.6	9.0	82	74	72	7.0	1.0	7.4	14200		5.5'	8.9	66	15	3.15
2200	10.1	142	40	102	11.65	9.1	84	78	76	7.4	0.9	7.5	14000		5.5'	9.0	70	15	3.15
3/29 0000	10.0	110	36	74	11.65	8.9	81	78	66	6.0	1.2	7.5	14000		5.0'	9.0	64	15	3.15
0200	10.0	104	35	69	11.65	9.4	87	85	66	6.0	1.2	7.5	13600		5.1'	9.3	68	15	3.15
0400	10.0	110	40	70	11.65	9.7	88	86	70	5.5	1.2	7.5	14300		5.0'	9.15	66	15	4.0
0600	10.0	110	40	70	11.6	8.6	89	87	68	5.8	1.5	7.4	14100		5.0'	9.0	73	15	3.5

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUMP						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
3/29																			
0800	10.0	120	32	88	11.6	9.15	86	80	70	8.2	1.2	7.6	14900	Max	4.9'	8.95	68	15	3.6
1000	10.0	116	28	88	11.6	9.1	90	86	72	8.0	1.1	7.7	14200	Max	4.0'	8.9	66	14	4.2
1200	10.0	116	32	84	11.5	9.15	86	82	68	7.9	1.2	7.8	14100	Max	4.7'	8.9	62	15	4.0
1400	10.0	120	32	88	11.6	9.2	88	82	68	6.2	3.2	7.7	14200	Max	6.0'	8.85	64	15	4.2
1600	10.0	118	32	86	11.65	9.0	85	82	70	6.0	2.0	7.5	14000		6.2'	8.9	64	15	4.2
1800	10.0	116	32	84	11.6	8.8	88	84	70	6.5	2.0	7.5	14000		Foam	8.9	66	15	4.2
2000	10.0	115	32	83	11.65	8.4	88	84	68	6.5	2.0	7.55	14300		Foam	8.9	64	15	3.5
2200	10.0	118	32	86	11.6	8.8	85	84	72	8.0	1.0	7.5	14200		Foam	9.0	68	15	3.5
3/30																			
0000	10.0	120	32	88	11.6	9.0	82	77	70	7.2	1.3	7.5	15000	15		8.9	15	3.5	
0200	9.95	122	32	90	11.55	8.9	80	77	66	6.7	1.2	7.3	15600	14.5		8.8	65	15	3.5
0400	9.95	125	32	93	11.6	8.8	82	76	70	6.9	1.4	7.3	15500	14.5		8.8	64	15	3.5
0600	9.95	127	31	96	11.6	8.7	84	78	73	7.0	1.5	7.35	15900	15		8.8	65	15	3.5
0800	9.9	130	30	100	11.6	8.5	94	82	64	8.0	0.8	7.6	15200	Max	5.6'	8.5	65	15	2.5
1000	9.95	124	30	94	11.6	8.6	88	84	76	7.5	0.9	7.4	15600	Max	4.4'	8.6	76	15	2.5
1200	9.95	128	30	98	11.6	8.9	90	80	68	5.0	0.9	7.9	13900	Max	5.0'	8.6	62	15	2.5
1400	9.95	128	28	100	11.65	9.1	92	82	68	8.4	1.4	7.4	14900	Max	7.0'	8.95	64	15	2.5
1600	9.9	126	26	100	11.0	9.0	90	80	69	8.0	1.5	7.4	14500			9.0	65	15	2.5
1800	10.0	128	26	102	11.7	9.0	92	80	70	8.0	1.5	7.4	14600		5.5'	9.0	64	15	2.5

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
~~3/30~~																			
2000	10.0	126	25	101	11.6	9.0	94	82	72	8.0	1.0	7.4	14400		5.5'	9.0	64	15	2.5
2200	10.0	124	30	94	11.65	9.0	94	84	72	7.5	1.5	7.4	14200		5.8'	9.0	66	15	2.5
3/31 0000	10.05	122	34	88	11.7	8.75	88	86	71	7.5	1.2	7.8	14300	12	4.8'	8.8	62	18	2.7
0200	10.0	122	32	90	11.65	9.0	87	86	70	7.0	1.2	7.6	14400	12	5.2'	8.9	62	16	2.7
0400	10.05	116	34	82	11.6	8.9	88	84	70	7.2	1.1	7.7	14200	12	3.2'	8.9	62	16	2.7
0600	10.1	102	36	66	11.5	8.9	89	84	71	7.0	1.2	7.7	14000	8	4.0'	8.8	64	16	2.7
0800	10.0	120	36	84	11.6	9.0	92	84	70	8.9	1.6	7.9	12600	Max	3.5'	8.8	62	16	2.7
1000	10.0	174	32	132	11.6	9.0	88	82	72	15	1.7	7.7	13800	Max	4.0'	9.05	58	16	3.0
1200	10.1	120	34	86	11.6	9.8	58	55	72	18	2.0	7.3	15500	Max	4.1'	9.3	50	16	3.5
1400	10.0	126	36	90	11.6	9.5	88	82	72	18	11.5	7.3	15700	Max	3.0	9.15	52	16	4.0
1600	10.0	128	34	94	11.65	9.4	80	80	70	16	2.0	7.4	14900		6.0'	9.2	50	16	3.5
1800	10.0	126	32	94	11.6	8.8	85	80	72	10	2.0	7.4	14500		6.0'	9.0	50	16	3.0
2000	10.0	128	34	94	11.65	8.0	87	82	70	5.5	2.0	7.4	14400	Max	Full	9.0	52	16	3.0
2200	10.1	130	34	96	11.65	8.5	85	82	72	6.0	1.5	7.4	14500		Full	8.9	54	16	3.0
4/1 0000	10.0	130	40	90	11.65	8.2	95	90	76	6.3	1.6	7.4	15000	Max	Full	8.5	82	16	3.4
0200	10.1	132	40	92	11.6	9.2	94	90	77	7.2	1.2	7.4	15100	Max	Full	8.8	83	16	3.0
0400	10.0	130	36	94	11.55	9.2	98	94	74	7.0	1.0	7.4	15000	Max	Full	8.9	70	16	3.5
0600	9.95	138	34	104	11.6	9.1	98	94	76	7.0	1.0	7.35	14900	Max	Full	8.8	64	16	3.7

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING(gpm)	TANK LEVEL	pH	ALK	#1	#2
4/1 0800	9.9	150	32	119	11.55	8.55	100	98	64	6.4	1.3	7.45	13600	Max	0.8'	8.65	64	16	3.0
1000	10.0	146	46	100	11.55	9.2	94	90	70	5.2	1.2	7.4	13600	Max	1.0'	8.05	80	16	3.0
1200	9.95	152	42	110	11.55	9.0	100	100	80	5.3	1.4	7.5	13800	Max	2.6'	8.75	68	15	2.0
1400	10.35	84	38	46	11.75	8.8	98	98	84	4.4	2.0	7.2	15600			8.7	66	15	2.0
1600	10.1	95	36	59	11.6	8.8	98	96	85	5.0	2.0	7.4	14800		5.0'	8.8	66	15	2.0
1800	10.0	96	34	62	11.65	8.9	98	95	84	5.5	2.5	7.4	14600		Full	8.9	68	15	2.0
2000	9.9	120	34	86	11.6	9.2	100	96	82	5.0	2.0	7.5	14200		Full	9.0	68	15	3.5
2200	9.9	118	34	84	11.7	9.3	98	94	80	5.0	2.0	7.4	14200		Full	9.1	68	15	4.5
4/2 1800	9.8	105	32	73	11.5	9.4	92	90	72	3.5	1.5	7.6	15800		4.5'	--	--	Full	Ful
2000	9.8	105	32	70	11.65	9.2	95	90	74	5.5	1.5	7.4	15900		3.0'	--	--	14	Full
2200	9.8	110	32	78	11.6	9.3	94	92	78	5.2	1.6	7.35	16200		6.0'	--	--	14 / 20	3.0 / Full
4/3 0000	9.75	110	40	70	11.6	8.2	96	94	75	6.6	2.0	7.6	16300	Max	2.5'	--	--	20 / 17	F / 4.0
0200	9.9	112	36	76	11.7	8.5	96	94	76	7.0	2.0	7.6	16400	Max	2.0'	--	--	17	3.0
0400	9.95	114	34	80	11.7	8.8	95	93	78	7.0	1.9	7.6	16700	Max	2.0'	--	--	17	3.0
0600	9.9	110	34	76	11.6	9.8	97	93	76	6.0	1.5	7.65	16000	Max	3.0'	--	--	17	3.5
0800	9.8	122	33	89	11.6	9.8	96	89	75	5.6	1.6	7.3	16800	Max		--	--	17 / 18	3.5 / 4.0
1000	9.9	107	33	74	11.75	9.3	105	96	77	5.2	1.5	7.5	14900	Max		--	--	18	4.2

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM FLUME						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
4/3 1200	9.8	124	33	91	11.6	9.2	96	92	76	5.1	1.5	7.5	15800	Max		--	--	15/18	4.0/Max
1400	9.8	111	34	87	11.65	9.2	106	98	80	4.0	1.6	7.45	15100	Max	5.5'	--	--	14	4.2/4.0
1600	9.9	115	32	83	11.6	9.1	100	98	78	4.5	1.5	7.7	16000	Max	5.0'	--	--	14/17	4.0/4.5
1800	9.9	120	34	86	11.6	9.4	98	97	74	4.5	1.8	7.5	15500	Max	6.0'	--	--	17	4.5
2000	9.9	115	34	81	11.65	9.3	98	66	74	5.0	1.5	7.5	15800	Max	6.5'	--	--	17	4.5
2200	9.9	116	34	82	11.6	9.1	100	96	75	80	1.5	7.5	15800	Max	6.0'	--	--	17	4.5
4/4 0000	9.9	110	34	76	11.55	9.4	93	91	78	8.0	1.5	7.7	14900	Max	6.0'	--	--	17	4.5
0200	9.9	110	34	76	11.5	9.3	93	90	78	7.5	1.8	7.6	14900	Max	6.3'	--	--	18	4.5
0400	9.9	106	34	72	11.5	8.5	91	88	76	7.0	1.7	7.6	14900	Max	6.5'	--	--	17+	4.5
0600	9.9	104	34	70	11.5	8.8	89	86	74	7.8	1.9	7.6	14700	Max	5.0'	--	--	17-	4.0
*0800	9.95	102	39	63	11.95	8.0	91	88	70	6.5	2.0	7.45	14700	Max	Full	--	--	17	4.0
1000	9.75	110	35	75	11.5	7.8	91	87	75	5.7	1.8	7.5	14800	Max	5.4'	--	--	17	3.3/2.5
1200	9.8	115	35	80	11.3	8.6	90	85	72	5.5	2.0	7.5	15000	Max	5.10'	--	--	17	2.5
1400	9.9	121	38	83	11.65	8.1	87	81	70	5.3	2.4	7.7	13000	Max	5.10'	---	--	17	2.5/2.0
1600	9.9	128	34	94	11.65	7.9	86	81	72	8.5	2.5	7.5	15300	Max	4.0'	--	--	16	1.5/2.0
1800	9.85	130	38	92	11.6	9.4	84	80	70	14	2.5	7.35	15500	Max	3.5'	--	--	16	2.5/3.0
2000	9.8	130	36	94	11.6	9.3	86	82	70	15	2.4	7.4	15400	Max	4.2'	--	--	16	3.0/2.8
2200	9.9	132	36	96	11.65	8.7	88	82	70	1.5	1.8	7.4	15600	Max	5.0'	--	--	16	2.8

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

*Increased lime .5 at 0800 - decreased .5 at 0820

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1				RAPID MIX #2	MAGNESIUM PUMP						CARBONATED SLUDGE				EFFLUENT FILTER #5		CO_2 SETTING (cfm)	
	pH	TH[1]	CH[2]	MH[3]	pH	pH	TH	CH	ALK	TURB	ACID TURB	pH	ALK	PUMP SETTING (gpm)	TANK LEVEL	pH	ALK	#1	#2
4/5 0000	9.9	132	34	98	11.65	8.9	90	88	73	5.5	1.5	7.5	15000	Max	5.4'	--	--	16	2.8
0200	9.8	128	32	96	11.6	9.1	89	86	72	6.7	1.5	7.6	14800	Max	5.8'	--	--	16	2.8/3.0
0400	9.9	126	32	94	11.7	8.85	88	86	71	6.0	1.4	7.5	15000	Max	6.4'	--	--	16	3.0
0600	9.8	124	34	90	11.6	9.0	91	89	71	7.5	1.7	7.35	15700	Max	6.8'	--	--	16	3.0
0800	9.9	133	33	100	11.6	8.6	94	88	69	6.1	1.5	7.25	16000	MAx	6.0'	--	--	15	3.0
1000	9.95	121	34	87	11.6	8.85	92	89	72	5.5	1.4	7.7	15800	Max	4.0'	--	--	15	3.0
1200	9.9	118	33	85	11.6	8.9	93	90	70	5.0	1.2	7.4	15600	Max	3.5'	--	--	15	3.0
1400	9.8	120	33	87	11.6	9.2	88	84	71	6.2	1.5	7.5	15300	Max	3.0'	--	--	15	3.0/3.5
1600	9.8	130	36	94	11.6	9.1	90	84	70	5.3	1.1	7.4	16000	Max	4.6'	--	--	15	3.5
1800	9.7	130	32	98	11.65	9.05	90	84	70	5.2	1.3	7.3	15500	Max	4.6'	--	--	15	3.5
2000	9.8	130	36	94	11.6	9.05	90	88	74	7.5	1.0	7.4	15000	Max	4.6'	--	--	15	3.5
2200	9.75	134	38	96	11.65	9.1	90	90	68	6.2	1.0	7.4	15800	Max	4.6'	--	--	15	3.5
4/6 0000	9.9	120	34	86	11.65	9.15	91	86	69	5.6	1.1	7.6	15900	Max	6.5'	--	--	15	3.5
0200	9.9	122	32	90	11.65	9.15	93	88	72	7.2	1.2	7.6	15900	Max	6.5	--	--	15	3.5
0400	9.9	128	36	92	11.65	9.05	95	90	74	6.0	1.2	7.6	15700	Max	6.0'	--	--	15	3.6
0600	9.9	130	36	94	11.65	9.1	93	88	72	7.0	1.1	7.45	16000	Max	5.8'	--	--	15	3.7
0800	9.95	122	36	86	11.65	8.5	97	90	68	6.1	1.0	7.65	15800	Max	5.6'	--	--	15	3.7
1000	9.8	125	35	90	11.6	8.6	95	88	70	5.6	1.0	7.5	16100	Max	4.3'	--	--	15	3.7

1 TH-Total Hardness
2 -CH- Calcium Hardness
3 MH-Magnesium Hardness

MONTGOMERY DEMONSTRATION OPERATING DATA

TIME & DATE	RAPID MIX #1 pH	RAPID MIX #1 TH[1]	RAPID MIX #1 CH[2]	RAPID MIX #1 MH[3]	RAPID MIX #2 pH	MAGNESIUM PLUME pH	MAGNESIUM PLUME TH	MAGNESIUM PLUME CH	MAGNESIUM PLUME ALK	MAGNESIUM PLUME TURB	MAGNESIUM PLUME ACID TURB	CARBONATED SLUDGE pH	CARBONATED SLUDGE ALK	CARBONATED SLUDGE PUMP SETTING (gpm)	CARBONATED SLUDGE TANK LEVEL	EFFLUENT FILTER #5 pH	EFFLUENT FILTER #5 ALK	CO_2 SETTING (cfm) #1	CO_2 SETTING (cfm) #2
4/6 1200	9.8	115	36	79	11.7	8.1	91	84	74	6.0	1.2	7.2	15800	Max	3.5'	--	---	15	3.7 / 3.2
1400	9.8	111	32	79	11.6	8.5	90	84	73	5.8	1.3	7.4	15300	Max	3.2'	--	--	15	3.2
1600	9.7	122	30	92	11.6	8.9	86	78	54	6.5	1.6	7.4		Max	4.3'	--	--	16	2.9
1800	9.8	128	32	94	11.25	9.25	86	82	72	7.4	1.1	7.4	17700	Max	4.7'	--	--	16	3.0 / 2.5

1 TH-Total Hardness
2 CH-Calcium Hardness
3 MH-Magnesium Hardness

APPENDIX B

VACUUM FILTER TESTS,

MONTGOMERY, ALABAMA

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(March 13, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
8 a.m.	STARTED								
9 a.m.	43.3		406.2	1.25	7.4			38.7	.5
10 a.m.									
11 a.m.	41.2		343.8	1.25	6.3	430	54	37.8	.5
12 N									
1 p.m.	40.5		280.2	1.25	5.1			46.7	.5
2 p.m.									
3 p.m.	39.1		289.8	1.25	5.3			45.2	.5

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(January 11, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
9 a.m.	STARTED								
10 a.m.	NO CAKE								
11 a.m.	35.7		209.4	.88	2.7	492	52	40.8	0
12 N	36.1		205.2	.88	2.6			40.7	0
1 p.m.	LINE ICED UP								
2 p.m.	38.3		190.2	.88	2.5			40.0	0
3 p.m.	35.3		173.4	.88	2.2	482	64	42.6	0

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(March 12, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
8 a.m.	STARTED			.88					0
9 a.m.	38.6		466.8	.88	7.5			39.9	0
10 a.m.				1.25					.5
11 a.m.	44.3		384.6	1.25	7.1	424	60	40.3	.5
12 N				1.25					.5
1 p.m.	43.6		387.0	1.25	7.1			39.6	.5
2 p.m.		7,800		1.25					.5
3 p.m.	43.2		354.6	1.25	6.5			39.1	.5
4:30 p.m.	CLOSED			1.25					.5

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(January 17, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
8:30 am	FILTER ON								0
9 am	14.2		190.2	.88	2.2			43.7	0
10 am	20.1		198.6	.88	2.3			45.4	0
11 am	27.9		219.0	.88	2.6	440	56	46.6	0
12 N	29.9		184.2	.88	2.2			43.5	0
1 pm	31.3		184.2	.88	2.2			48.5	0
2 pm	35.1		165.6	.88	1.9	470	62	45.0	0
3 pm	32.3		191.4	.88	2.2			45.9	0

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(February 21, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
9 am	STARTED			.88					
10 am				.88					
11 am	41.6	7,500	3.012	.88	3.9			35.8	
12 N				.88					
1 pm	46.9		3.018	.88	3.9	396	56	35.2	
2 pm				.88					
3:30 pm	42.2		3.288	.88	4.2			35.8	
4:20 pm	CLOSED			.88					

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(January 18, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
9 am	STARTED FILTER								0
10 am	26.9		148.8	.88	1.9			43.5	0
11 am	MISSED								
12 N	33.1		154.2	.88	2.0	456	96	45.4	0
1 pm	33.0		185.4	.88	2.4			47.0	0
2 pm	31.7		154.8	.88	2.0			45.0	0
3 pm	32.1		162.0	.88	2.1	508	60	46.3	0
4 pm	30.8		135.0	.88	1.7			46.3	0

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(February 23, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
8:15 am	STARTED								
9 am	43.4		303.0	.88	3.9			36.796	
10 am				.88					
11 am	43.7	7,400	307.2	.88	4.0	344	34	37.408	
12 N				.88					
1:30 pm	39.9		353.4	.88	4.6			36.393	
2 pm				.88					
3 pm				.88					
4 pm	24.2		169.5	.88	2.3				
4:25 pm	CLOSED								

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(February 28, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
9 am	50.7		586.2	.88	7.6			34.43	0
11 am	57.1		684.6	.88	8.8			34.31	0
1 pm	49.9		451.8	1.25	8.3	334	38	36.18	.5
2 pm	50.4		310.8	1.666	7.6			35.25	1.0
3 pm	49.5		349.2	2.727	14.0			35.33	2.0

MAGNESIUM CARBONATE PROCESS

Sludge Handling Data

(March 5, 1973)

Time	Feed Sludge Solids (%)	Filtrate Alk	Solids (g/ft^2)	Drum Speed (RPM)	Filter Rate ($lb/ft^2/hr$)	Cake Analysis (As $CaCO_3$) Ca	Mg	% Moisture	Belt Setting
8 am	49.5		450.6	1.666	11.0			38.08	1.0
11 am	48.8		529.2	1.25	9.7			37.84	.5
1 pm	49.2	9,000	409.2	1.666	10.0	524	35	39.05	1.0
2 pm	43.9		367.2	1.666	9.0			40.29	1.0

APPENDIX C
ROUTINE DATA SHEETS, MELBOURNE, FLORIDA

Reproduced from best available copy.

CITY of MELBOURNE, FLORIDA
NORTH WATER TREATMENT PLANT

DATE 8 Dec 73 Treatment with $MgCO_3$ as a Recycled Coagulant DAY Sat

	#1 CENTER					CLARIFIER (WEIR)							FILTERED FINISHED WATER								SLUDGE CARBONATOR		
TIME	pH	P ALK	TOTAL ALK	OH	CO_3	pH	P ALK	T ALK	T H	T Cc	COLOR	THRES. ODOR	pH	P ALK	T ALK	T HARDNESS	N C H	Ca	Mg	COLOR	THRES. ODOR	pH	ALK	COLOR
2400	11.5	154	202	101	88	8.1					31		7.59	0	188	212	24	60	10	35		7.3		
0100	11.2					8.1	6	128	132	164	30		8.1									7.2	6100	4104
0200	11.2					8.6					30		8.2									7.5		
0300	11.4					8.7					28		8.3	0	ODOR TEST						mg	7.5		
0400	11.3	162	198	124	74	8.6					29		8.3	0	124	164	42	152	14	30		7.4		
0500						8																		
0600																								
0700	11.2					8.5					29		8.2									7.8		
0800	11.25	168	210	126	84	8.5					32		8.25	0	140	184	44	182	2	25		7.8		
0900	11.1					7.6	2	102	106	142	32		7.95							28		7.42	6400	7000
1000	11.25					8.8					35		8.3							32	Mg	7.32		
1100	11.14					8.65					28	Mg	8.4									7.0		
1200	11.15	142	172	102	82	8.7					32		8.3		104	144	40	140	4	32		7.0		
1300	11.2					8.8	6	24	126	122	28		8.3							30		7.05	7600	
1400			170	106		8.2																		
1500		144		84		8.4			C															
1600	11.2			72		8.7					25		8.5	2	100							7.5		
1700	11.25					8.5					25		8.4									7.6		
1800	11.4					8.42					40		8.3									7.4		
1900	11.25					8.2							8.2									7.25		
2000	11.3			132	88	8.6							8.2	2			28							
2100	11.3					8.1	4				31		8.2									7.21		
2200	11.35					8.4					30		8.1									6.9		
2300	11.35					8.4							8.2									6.9		
Total																								
AVG.	11.26	154	194	113	81	8.5	5	124	170	160	30		8.23	1	135	171	26	165	6	30		7.29	6800	5400

	RAW WATER											
Time	pH	Total Alk	Hardness Total	N C H	Ca	Mg	Chloride	Total Iron	Fluoride	Color	Temp. F°	
0100	7.4	36	62	26	50	12				125	74	
0700	7.2	38	60	22	48	12	38			150	73	
1600	7.4	43	95	15	72	8				100	77	
Total	22	117	160	63	148	92	38			380	220	
Average	7.3	39	60	20	49	11	18			127	73	

SHIFT	OPERATOR
2400-0800	Curtis
0800-1600	Lynch
1600-2400	Jones

REMARKS
0230 PM Water 8.2

CITY OF MELBOURNE, FLORIDA

NORTH WATER TREATMENT PLANT

DATE: 8 Nov 73

Treatment with $MgCO_3$ as a Recycled Coagulant

DAY: Thurs

TIME	RAW MGD	MAGNESIUM Recycle GPM	MAGNESIUM Make-Up lb	CO_2 Weir GPM	CO_2 Sludge GPM	COAGULANT AID Pump Set.	COAGULANT AID ML/Min	COAGULANT AID Time Mix	LIME Mach. Set.	LIME Lbs. Load		
12MN	13	15	21	16	320	2.5			375			
1AM	13	15	21	16	320	2.5			375			
2	13	15	21	16	330	2.5			375	1550		
3	13	15	21	16	340	2.5			375			
4	13	15	21	16	340	2.5			375			
5		Plant off		0415								
6		Plant on		0625						500		
7	13	15	21	16	360	2.5			375			
8	13	15	21	16	300	2.5			375			
9	13	15	21	16	360	2.5			375			
10	13	15	21	16	360	2.5			375			
11	13	15	21	16	310	2.5			375			
12N	13	15	21	16	340	2.5			375			
1PM	13	Plant off		1300								
2		Plant on		2206								
3	13	15	21	11	300	2.5			375	1550		
4	13	15	21	11	340	2.5			375			
5	13	15	21	11	300	2.5			375			
6	13	15	21	16	340	2.5			375			
7	13	15	21	16	340	2.5			375			
8	13	15	21	16	340	2.5			375			
9	13	15	21	16	340	2.5			375	1150		
10	13	15	21	16	340	2.5			375			
11	13	15	21	16	320	2.5			375	1050		
12MN												
TOTAL			420							4550		

MGD METER READING (RAW) # I SIDE

PRESENT	280726
PREVIOUS	279624
MGD PUMPED	1102

OPERATORS

12 - 8 Curtis

8 - 4 Lynnette

4 - 12 [illegible]

FILTERS	#1	#2
PRES. WASH	7.8	7.8
PREV. WASH	128	129
HRS. RUN	40	39
B.W. END	390	490
B.W. START	290	390
GALS. USED	100	100
GAL./MIN.	6	6
MIN. WASH	20	20

REMARKS

1200 Lime Carb CO_2
PLANT OFF AT 13:00 FOR MAINT.
1445 Plant On

CHEMICAL INVENTORY

	QUICK LIME	COAGULANT AID	CO_2	$KMNO_4$	HYDRATED LIME	$MgSO_4$	CHLORINE	CARBON
Pounds on hand			27000			5720		
Used			4,000		4550	4.20		45
Pounds on hand			23,000			3.300		
P. P. M.			436.01		495.97	45.79		4.91

APPENDIX D

SUMMARY OF DAILY AVERAGE RESULTS

MELBOURNE, FLORIDA

Date	Raw Water		Coagulation	Filtered Water			Carbonated Sludge	
	Magnesium	Color	pH	Hardness		Color	Alkalinity	Color
				Total	Magnesium			
9/13/73			11.35	157	2.4	35.4	20,666	15,400
9/14/73			11.31	172	10.0	44.8	23,166	18,666
9/15/73			11.27	132	7.3	35.3	21,083	14,066
9/16/73			11.31	152	10.3	37.4	21,333	13,516
9/17/73			11.28	173	6.0	38.7	20,900	13,800
9/18/73			11.37	181	6.67	47.9	22,000	12,033
9/19/73	12.66	195	11.43	146	7.33	42	27,700	18,000
9/20/73	12	215	11.29	167	7	59	11,733	14,750
9/21/73	11.3	230	11.39	117	5.3	30	11,333	17,250
9/22/73	13.3	220	11.38	137	6.3	38.6	9,866	14,166
9/23/73	12	227	11.4	154	11	36	8,134	11,884
9/24/73	15.3	200	11.44	171	8.3	41.8	9,033	10,750
9/25/73	14	208	11.45	126	3	36	8,966	10,000
9/26/73	12	208	11.38	130	2	41	8,633	9,750
9/27/73	14	185	11.43	141	2.8	42.7	7,866	10,083
9/28/73	12	178	11.41	141	5.6	36	7,000	9,666
9/29/73	15	175	11.41	124	4.5	38	8,333	11,416
10/1/73	14	183	11.29	155	4	39	7,300	7,250
10/2/73	14	175	11.41	111	3	35	6,543	6,350
10/3/73	12	175	11.45	133	3.5	36	6,350	7,083
10/4/73	12	176	11.38	137	9	91	7,433	6,916
10/5/73	14	190	11.35	171	5	34	7,100	7,000
10/6/73	12	208	11.38	164	11	26	7,400	7,100
10/7/73	15	175	11.33	169	6	31	6,366	3,983
10/8/73	10	167	11.33	204	13	35	6,100	6,600
10/9/73	12	158	11.35	132	5	29	6,400	5,700
10/11/73	12	216	11.28	112	2	30	5,616	6,116
10/12/73	11	200	11.33	117	4.6	34	5,053	7,316
10/16/73	7	188	11.24	196	5	34	5,900	6,850
10/17/73	8	222	11.4	166	6.8	36	6,200	7,640
10/18/73	10	192	11.2	158	8	34	4,833	5,350
10/19/73	11	175	11.24	183	1.5	34	6,250	6,925
10/20/73	7	167	11.34	204	4.6	33	6,233	5,500
10/21/73	6	195	11.25	211	10	34	5,800	5,930
10/22/73	9	172	11.27	209	4.66	33	5,770	5,430
10/23/73	15	147	11.25	226	5.7	38	5,367	4,917
10/24/73	11	177	11.27	191	4.7	34	5,766	5,255
10/25/73	7	138	11.25	184	7	37	5,566	7,633
10/26/73	10	138	11.28	196	7	32.5	6,040	6,940
10/27/73	13	138	11.64	221	0	36	4,050	11,250
10/28/73	5	183	11.36	215	7	41	5,167	7,316
10/29/73	8	125	11.23	195	12	33	5,800	6,700
10/30/73	9	175	11.2	154	8	28	6,900	7,233
10/31/73	8	183	11.32	154	6	31	4,700	4,900
11/1/73	8	148	11.26	185	4	31	5,400	4,233
11/2/73	11	116	11.22	186	10	31	5,366	5,350
11/3/73	11	146	11.3	153	5	33	5,333	6,566
11/4/73	6	146	11.5	161	12	28	5,800	6,016
11/5/73	13	130	11.26	155	7	29	5,967	4,283
11/6/73	28	150	11.33	186	8	30	6,700	6,250
11/7/73	11	185	11.4	198	6	30	7,567	7,267
11/8/73	11	127	11.26	171	6	30	6,280	5,400
11/9/73	8	147	11.29	165	4	23	5,967	6,733

Date	Raw Water		Coagulation	Filtered Water			Carbonated Sludge	
	Magnesium	Color	pH	Hardness		Color	Alkalinity	Color
				Total	Magnesium			
11/11/73	15	150	11.4	209	5	32	6,167	5,067
11/12/73	15	138	11.4	175	5	26	6,267	6,650
11/13/73	14	142	11	218	10	34	6,600	6,167
11/14/73	13	168	11.38	197	5	42	7,400	7,200
11/15/73	19	142	11.3	206	6	34	8,400	7,317
11/16/73	12	175	11.9	212	5	39	9,550	10,500
11/17/73	12	150	11.4	192	7	33	10,520	11,100
11/18/73	9	133	11.3	205	6	36	11,833	12,500
11/19/73	12	147	11.38	201	2	31	7,400	6,800
11/20/73	7	133	11.33	192	2	29	8,560	8,880
11/21/73	11	142	11.38	201	5.3	28	8,700	11,680
11/22/73	7	147	11.35	177	1.6	23	8,160	9,500
11/23/73	13	147	11.44	139	5.6	36	8,080	10,200
11/24/73	14	166	11.4	184	5	27	8,600	10,300
11/25/73	17	160	11.32	195	4	37	8,680	8,800
11/26/73	13	134	11.3	190	7	40	7,850	8,500
11/27/73	5	133	11.3	155	8	34	8,700	7,700
11/28/73	7	142	11.3	179	4	34	9,200	9,300
11/29/73	6.3	183	11.45	172	3.6	27	6,966	4,883
11/30/73	12	142	11.47	185	13	31	7,333	6,750
12/1/73	8	130					8,740	9,000
12/2/73	10	129					8,266	7,733
12/3/73	8	158					6,800	6,600
12/4/73	12	150	11.45	151	4	24	6,500	5,750
12/5/73	11	157	11.4	122	13	29	6,120	4,920
12/6/73	16	142	11.35	134	9	30	6,570	5,550
12/7/73	8	167	11.52	192	5.5	29.1	6,560	5,900
12/8/73	8	163	11.45	226	8	34	6,800	5,800
12/9/73	17	183	11.5	226	4	30	6,900	6,025
12/10/73	9	125	11.5	246	6	26	8,633	7,400
12/11/73	12	113	11.6	244	5	13	7,200	6,143
12/12/73	11	133	11.65	200	4	12	7,467	5,800
12/13/73	12	142	11.7	197	12	11	6,700	5,350
12/14/73	9	125	11.53	252	4	11	6,600	4,500
12/15/73	9	133	11.5	210	4	10	6,800	4,983
12/16/73	14	138	11.6	229	14	9	6,880	5,200
12/17/73	10	252	11.6	236	7	21	7,760	6,960
12/19/73	10	125	11.6	207	1	15	8,267	7,467
12/20/73	14	152	11.5	170	7	20	6,700	5,317
12/21/73	19	208	11.6	216	5	19	7,920	8,200
12/22/73	9	193	11.5	222	5	21	7,100	5,717
12/23/73	16	125	11.6		7	22	6,800	8,340

APPENDIX E

E.P.A. ANALYSIS FOR HEAVY METALS AND COMMENTS, MELBOURNE, FLORIDA

RESULTS OF TRACE ANALYSIS, MELBOURNE, FLORIDA

PERFORMED BY SOUTHEAST ENVIRONMENTAL

RESEARCH LABORATORY, U.S.E.P.A., ATHENS, GEORGIA

Parameters	Raw Water	Magnesium Treated Water	Alum Treated Water
Chloride	50	48	46.0
Sulfate	<25	<25	47.0
Sodium	20	20	20.0
Lithium	<0.1	<0.1	<0.1
Barium	<0.05	<0.05	<0.05
M.B.A.S.	<0.25	<0.25	<0.25
Arsenic	<0.005	<0.005	<0.005
Selenium	<0.005	<0.005	<0.005
Cyanide	<0.02	<0.02	<0.02
Chromium	0.00	0.00	0.00
Silver	0.00	0.00	0.00
Copper	0.00	0.009	0.017
Manganese	0.00	0.00	0.006
Lead	0.00	0.00	0.00
Iron	0.24	0.025	0.046
Cobalt	0.00	0.00	0.00
Cadmium	0.00	0.00	0.00
Zinc	0.031	0.076	0.19
Nickel	0.00	0.00	0.00

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Southeast Environmental Research Laboratory, College Station Road, Athens, Georgia 30601

SUBJECT: Organic Analysis of Samples from North Melbourne Water Treatment Plant

DATE: December 14, 1973

FROM: 4ASC/Finger

TO: Gary Hutchinson

Summary

There were no organic chemicals detected in the three water samples taken November 1973 from various sources in the treatment process. The analysis was by gas chromatography, therefore only organics that vaporize under our GC conditions would be detected.

Action

Transmittal of data.

Background

Your memo of October 5, 1973 to Mr. John A. Little.

James H. Finger
Chief
Chemical Services Branch

EPA Form 1320-6 (Rev. 6-72)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Southeast Environmental Research Laboratory, College Station Road, Athens, Georgia 30601

SUBJECT: Significance of Organic Analysis of North Melbourne Samples

DATE: January 8, 1974

FROM: 4ASC/Finger

TO: 4AM/Hutchinson

Summary

This memo is to provide further comment on our organic analysis of the three North Melbourne, FL Water Treatment Plant samples received November 15 and labeled Alum, Raw and Mag. The sampling dates were not reported to us.

As I mentioned in my last memo on these samples, we used gas chromatography for analyzing the samples, therefore we would only detect organics that vaporize at our GC operating conditions. CCE and CAE data can't be compared to GC data because they are based on the weight of the residue remaining after evaporating the chloroform and aocohol extracts. Since these samples are from Florida I would guess that the CCE and CAE could consist of high boiling natural organics that do not vaporize at GC conditions such as the tannic acids.

Action

For your information.

Background

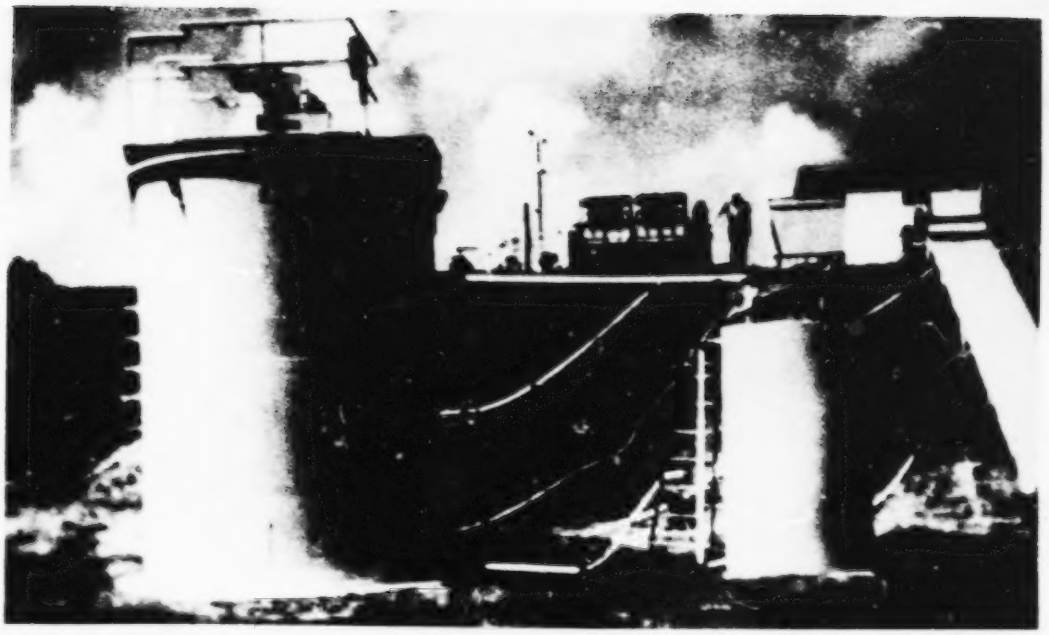
Further comment pertaining to my memo of December 14, 1973.

James H. Finger
Chief
Chemical Services Branch

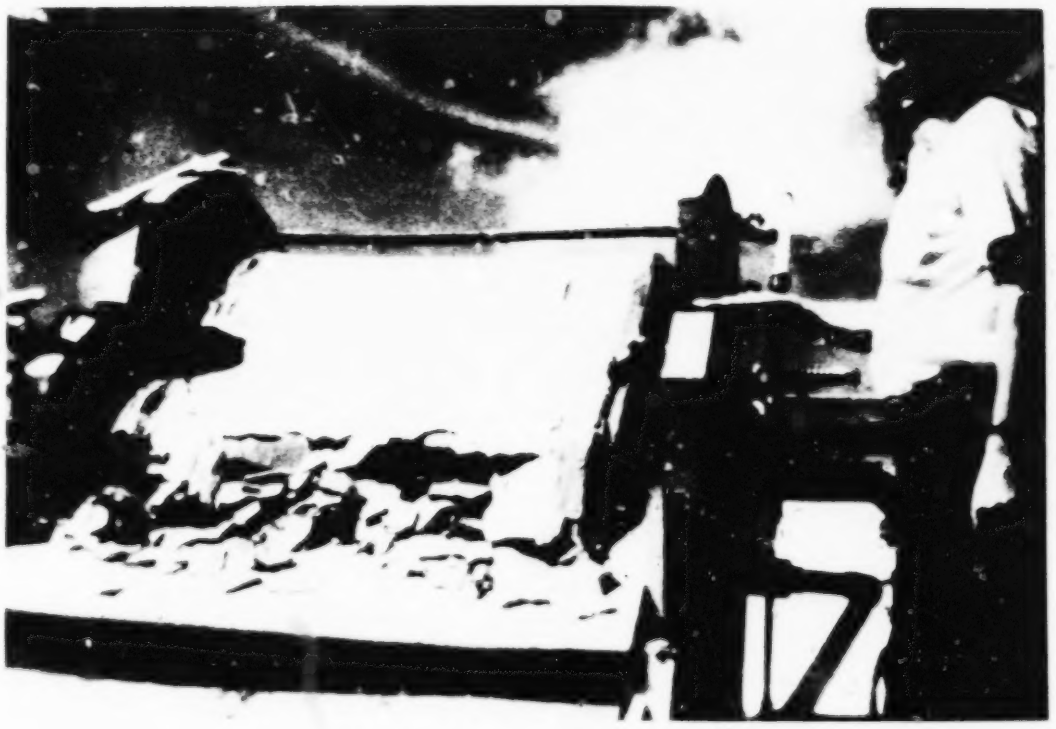
EPA Form 1320-6 (Rev. 6-72)

APPENDIX F

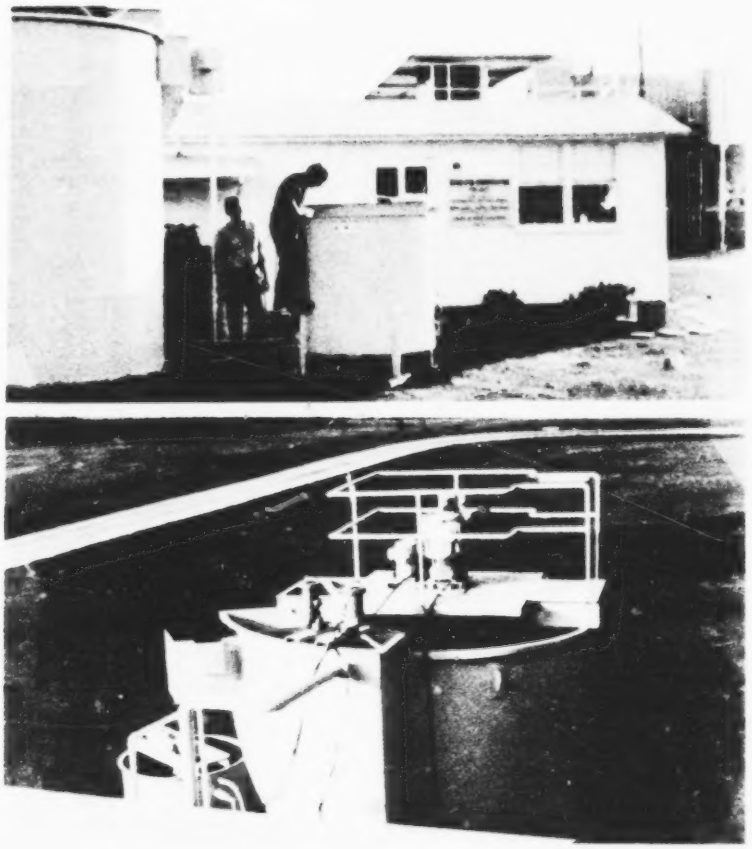
PHOTOGRAPHS OF THE MONTGOMERY AND MELBOURNE FACILITIES



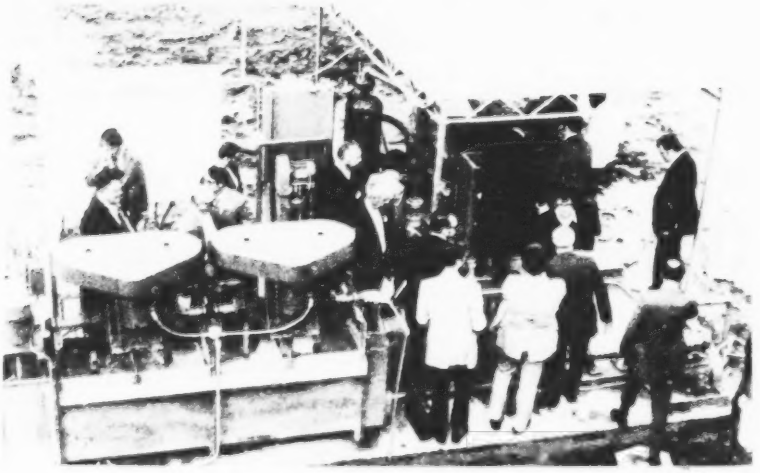
Melbourne Full Scale Facility



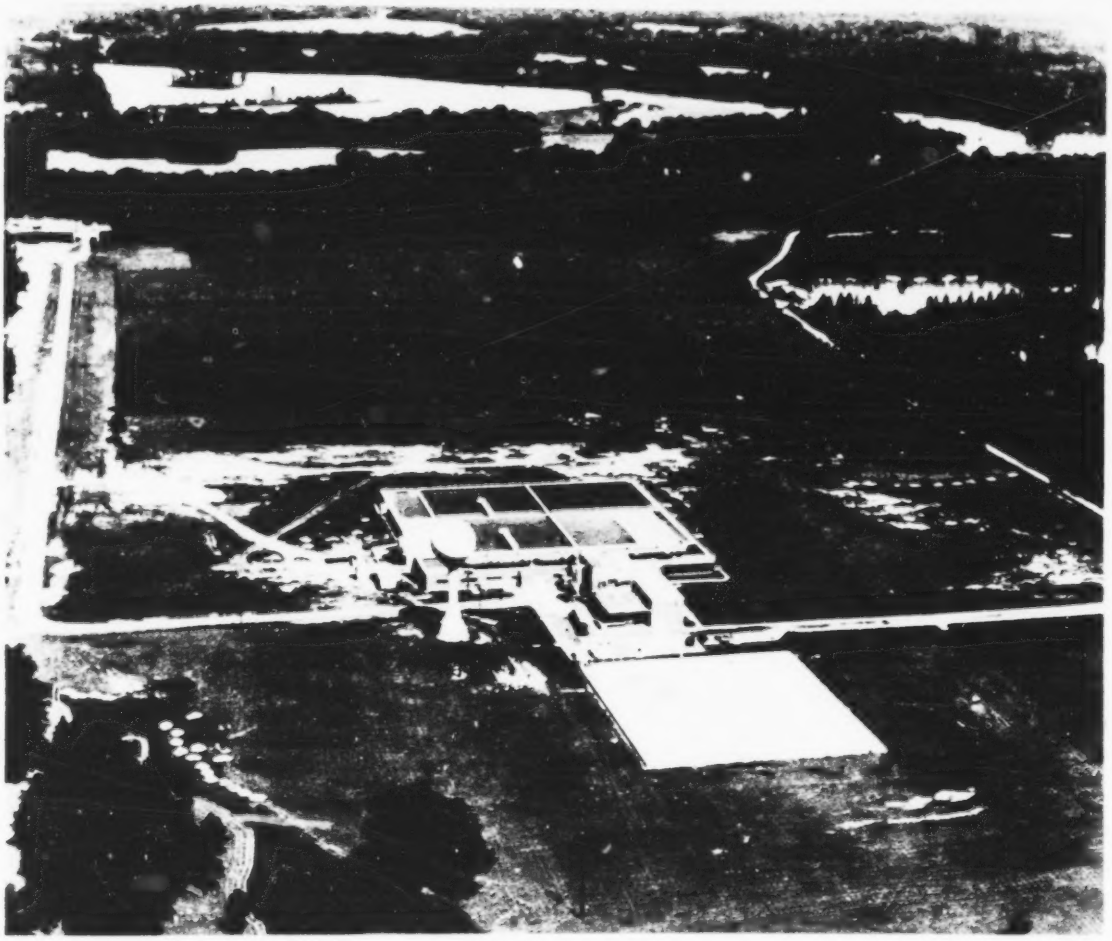
Melbourne Vacuum Filter



Montgomery Pilot Plant Facility



Montgomery Full Scale Magnesium
Recovery Facilities



Plant Scale Study Facilities,
Montgomery, Alabama